ETT TTEB

A Review of Energy Calculation Methods for Warehouses and Light Industrial Buildings

A RESEARCH REPORT

Canada

A Review of Energy Calculation Methods for Warehouses and Light Industrial Buildings

A RESEARCH REPORT

Sponsored by the
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Prepared by
H.F. Sullivan
under a sub-contract from the
Building Engineering Group
Waterloo, Ontario

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The Buildings Energy Technology Transfer Program (BETT) of EMR has been created to assist building owners, users and practitioners active in the design, construction and operation of buildings in identifying technical obstacles to energy conservation. Through a nationwide network of research agencies and private sector consultants, BETT carries out research and development projects and provides the audiences mentioned above with technical reports, how-to manuals, training manuals, audio-visual aids and data bases to help them overcome these obstacles.

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ABSTRACT/RESUME

This report outlines the state of practice regarding building energy analysis methods and simulation procedures. Although the building category of interest in the present study is the warehousing and light industrial building sector, it is evident that most detailed methods can be applied to this sector.

The analytical methods reviewed cover the full range of sophistication from "degree-day methods" through "bin methods" to "detailed methods". Two appendices of this report contain several matrix summaries (available in the literature) of the characteristics of a large number of the existing computer programs for building load calculations and energy analysis.

Recent developments regarding energy analysis methods are reviewed. The specific areas of weakness in existing programs are noted, and recommendations for future research and development are presented.

***

Dans le présente rapport sont exposées les façons courantes d'appliquer des méthodes d'analyse et des procédés de simulation ayant pour objet la consommation d'énergie dans les bâtiments. Quoique la catégorie de bâtiments étudiée soit celle des entrepôts et des bâtiments industriels à structure légère, il va de soi que la plupart des méthodes détaillées peuvent s'appliquer à ce secteur.

Tout l'éventail des méthodes sophistiques y est examiné, des "méthodes des degrès-jours" aux "méthodes détaillées" en passant par les "méthodes des gammes de température". Deux annexes au présent rapport comportent plusieurs matrices récapitulatives (empruntées à la documentation consultée) des caractéristiques d'un grand nombre de programme machines servant actuellement au calcul de la consommation d'énergie des bâtiments et à l'analyse de cette consommation.

Des faits récents propres aux méthodes d'analyse de la consommation d'énergie y sont étudiés. Les points faibles des programmes actuels y sont notés et des recommandations en vue de futurs travaux de recherche et de développement, présentés.

Le lecteur trouvera un sommaire en français de ce rapport à la page iii.

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The Buildings Energy Technology Transfer Program (BETT) was initiated by the Department of Energy, Mines and Resources (EMR) of the Government of Canada in late 1981. The principal objectives of this program are:

- to identify the potential for energy conservation in both new and existing buildings
- to determine R, D and D requirements and their priority in order to exploit this potential
- to perform and/or expedite the necessary R, D and D
- to effectively transfer the necessary technology to the appropriate individuals, groups or agencies
- to provide technological support to EMR in the development of policy and programs.

The Building Engineering Group (BEG) was selected* by EMR to develop and execute a comprehensive R, D and D program for energy conservation in the warehousing and light industrial building sector. BEG is a semi-autonomous, non-profit agency associated, through the Waterloo Research Institute (WRI), with the University of Waterloo. This multi-disciplinary group attempts to provide a comprehensive range of R and D services to the building industry.

The warehouse and light industrial building sector is particularly important because:

- the square footage of building space encompassed by this category is second only to that of the residential building category
- to date very little R and D, energy-related or otherwise, has been directed towards this building category
- the nature of these buildings, both new and existing, makes them particularly amenable to some degree of energy conservation.

* DSS Number 02SQ.23380-1-6665-4 Serial OSQ81-00137 and Proposal Number WRI 109-01, September 20, 1981

In the initial phase of the R, D and D program developed by BEG, the priorities were to:

establish a statistical profile of the building category

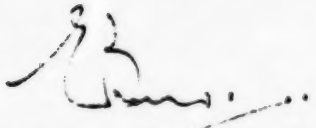
develop a comprehensive review of the current state of practice

initiate the development of a portfolio of representative case histories.

Ten related studies are being undertaken in this initial phase. Seven of these studies provide either supporting documentation or input for a comprehensive state-of-practice report.

This particular report entitled "A Review of Energy Calculation Methods for Warehouses and Light Industrial Buildings" was prepared by Dr. H.F. Sullivan of the University of Waterloo. The intent with this study was to review and assess these issues from a warehousing and light industrial building perspective, to identify gaps and needs and then to establish tasks and priorities for further work.

This report is an early product of what is intended to be a concerted multi-year program of research, development, demonstration, dissemination and evaluation. Feedback with regard to the report or related issues is welcomed and should be directed to the undersigned.



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Le présent rapport décrit les façons courantes d'appliquer les méthodes, d'analyse et les procédés de simulation propres à l'étude de la consommation d'énergie dans les bâtiments. Quoique la catégorie de bâtiments qui fait l'objet du présent rapport est celle des entrepôts et des bâtiments industriels à structures légère, il va de soi que la plupart des méthodes détaillées peuvent s'appliquer à ce secteur.

Les méthodes d'analyse de la consommation d'énergie dans les bâtiments qui ont été élaborées et décrites dans la documentation font appel à un grand éventail de techniques sophistiquées. Une classification introduite récemment (par l'American Society of Heating, Refrigerating and Air-Conditioning Engineers - ASHRAE) fail la distinction entre les méthodes ;a mésure unique, les méthodes à mesures multiples simplifiées et les méthodes de simulation détaillé.

Les méthodes à mesure unique comprennent la "méthode des degrès-jour modifiée", très connues, pour les calculs propres au chauffage, et la "méthode de l'équivalent heures-pleine charge" et la "méthode des degrès-jour de refroidissement", pour les calculs propres au refroidissement.

Les méthodes à mesures multiples simplifiées comprennent les "méthodes des gammes de température" et "les méthodes des gammes de température modifiées "procédé T.C. 4.7 de l'ASHRAE)". Cette dernière a recémment été comparée avec des méthodes de simulation détaillée lors de l'analyse de plusieurs types de bâtiments, y compris des bâtiments commerciaux, un hôpital, un entrepôt et un magasin à rayons. La comparaison des résultats a indiqué qu'ils étaient raisonnablement précis, mais il est nécessaire de perfectionner les méthodes des gammes de température modifiées pour qu'elles intéressent davantage les utilisateurs.

Les méthodes de simulation détaillé, qui comprennent généralement l'exécution de calculs à toutes les heures, peuvent devenir très complexes. On estime à plus d'une centaine le nombre de répertoires de ces programmes

machines, qui englobent ensemble une foule d'éléments complexes. La documentation en la matière comporte un certain nombre de répertoires de ces programmes et précise les possibilités d'y accéder. Bon nombre de ces programme machines sont asujettis à des brevets et, de ce fait, ne sont accesibles d'aucune façon aux particuliers on ne sont accessibles que d'une façon restreinte interdisant l'accès aux calculs algorithmiques. Seules quelques programmes, y compris tous les renseignements concernant le code machine et les modes de calcul, sont accesibles de manière générale.

Les descriptions de programmes que contiennent ces repétoires proviennent généralement de leurs auteurs. Très peu de renseignements permettent de comparer les possibilités d'application, la souplesse d'utilisation et l'exactitude de ces programmes. Et l'on en sait encore au moins au sujet de leur validité.

Deux annexes au présent rapport comportent plusieurs matrices récapitulatives des caractéristiques d'un grand nombre de ces programmes, matrices préparées à partir des répertoires susmentionnés.

L'évolution récent survenue dans le domaine des méthodes d'analyse de la consommation d'énergie était l'objet d'une réunion tenue récemment par l'ASHRAE qui regroupait neuf sommités en la matière. Parmi les nouveautés recommandées, il y a lieu de citer l'exécution de calculs à des internalles plus courts qu'à chaque heure, afin de pouvoir modéliser les systèmes de contrôle de gestion de l'énergie (S.G.É.), la modélisation de bâtiments tout entier sous la forme de modèles à pièces multiples, une attention plus marquée en ce qui a trait à l'éclairage naturel et l'élaboration suivie de simulations aux fins de nouveaux produits et systèmes. La modélisation de l'infiltration, du transfer de chaleur par voie souterraine et des systèmes solaires passifs affiche des faiblesses. Le traitement de l'entrée des données, en général, influe d'une façon cruciale sur l'exactitude des résultats de la simulation. L'utilisation des micro-ordinateurs va en grandissant et l'on s'attend à ce qu'il soit nécessair d'étendre le champ

d'application des méthodes simplifiées d'analyse de la consommation d'énergie de manière à englober les bâtiments à vocations multiples et les systèmes complexes de chauffage, de ventilation et de climatisation.

L'évolution récente survenue au Canada dans le domaine des méthodes d'analyse de la consommation d'énergie s'est matérialisée par le lancement d'un programme par Travaux Publics Canada (T.P.C.), financé en partie par Énergie, Mines et Ressources Canada (E.M.R.). Ce programme d'étude qui prévoit l'examen, le soutien et le perfectionnement de mécanismes d'analyse de la consommation de l'énergie (applicables à toutes les catégories de bâtiments) en est actuellement à l'étape de l'examen, à laquelle l'industrie est invitée à participer par l'apport de données. Ces renseignements sont recueillis au moyen d'un questionnaire (annexe C) et d'une série de réunions qui doivent se tenir à divers endroits d'un bout à l'autre du Canada (voir le document de travail connexe à l'annexe D). Ce rapport recommande entre autres que les chercheurs chargés de la présente étude collaborent étroitement avec le personnel du programme de T.P.C. et d'E.M.R. pour éviter le recoupement des efforts et faire en sorte que les résultats des programmes se complètent.

Voici les principales conclusions et recommandations de ce rapport:

On désire voir élaborer des programmes d'analyse simplifiée de la consommation d'énergie, que l'on pourrait appliquer aux bâtiments à vocation autre que résidentielle.

L'utilisation accrue des micro-ordinateurs et des méthodes simplifiées d'analyse de consommation d'énergie laisse entrevoir la nécessité, à défaut d'une validation intégrale de ces méthodes simplifiées, d'en évaluer les limites d'applications, par suite hypothèses émises à des fins de simplification.

Parmi les éléments de la consommation d'énergie auxquels il serait souhaitable de consacrer davantage d'efforts de recherche, il faut mentionner l'infiltration, le transfer de chaleur

par voies souterraines, les modèles à vocations multiples, la simulation de nouveaux systèmes de chauffage, de ventilation et de climatisation, y compris de leurs dispositifs de contrôle, ainsi que la modélisation des systèmes solaires passifs.

L'évaluation des besoins de l'industries est une priorité, et il faut soutenir sans réserve le programme actuel de T.P.C. et d'É.M.R.

L'élaboration d'un programme unique pouvant s'appliquer à différentes étapes, de la conception initiale à celle des travaux d'ingénerie détaillés, est des plus souhaitable. Une telle initiative faciliterait la collaboration entre les ingénieurs et les architectes dans la réalisation de bâtiments et de système de chauffage, de ventilation et de climatisation à bon rendement énergétique. Il est donc recommandé de déployer des efforts en vue d'élaborer un tel programme.

1. Objective

The purpose of this report is to outline the state of practice regarding building energy analysis methods and simulation procedures with specific attention to the needs of the warehouse and light industrial building (WLIB) category of buildings.

2. Scope of Work

Buildings can be grouped or classified in a wide variety of ways depending upon use, construction, number of stories, type of occupancy, etc. Although some building energy analysis methods might be general enough to apply to all building categories, in many cases the particular and common characteristics of a single class of buildings may permit simplified and/or specialized energy analysis methods to be developed for that building sector.

The building category of interest in the present study is the warehousing and light industrial building sector, also termed the service industrial sector.

From an energy analysis viewpoint, this category represents a broad spectrum, ranging from buildings with internal environments over which there is little or no control to very tightly controlled environments as in cooled and refrigerated warehouses.

The ultimate purpose of the overall research program, of which this study is a component, is to arrive at and disseminate guidelines for energy conservation for one particular building category. The guidelines will be used by many different groups, ranging from architects involved in the design of new buildings, to engineers involved with the HVAC systems and building components of both new and existing building stock, to owners concerned

primarily with the capital costs of constructing energy-efficient buildings as well as the operating costs in a time of rapidly escalating fuel prices. Each group of users has very different requirements for energy analysis methods. This study attempts to take into account the needs of all interested parties.

A first step in arriving at a classification of analysis methods is to define some of the terminology. The assumption is made that, in general, both heating and cooling of buildings are of interest. Since analysis of the energy required for cooling generally requires a more complex set of calculations than for heating, much of the discussion is approached from the point of view of cooling. It should be understood that the heating situation is in many respects subject to the same considerations (e.g., effect of thermal lag in wall, floor and roof components, etc.).

3.1 Terminology

In a cooling load calculation there are several related but distinct time-dependent heat flow rates which must be clearly differentiated. They are as follows:

- space heat gain
- space cooling load
- space heat extraction rate
- cooling coil load.

The definitions of these quantities are taken from Reference 1.

3.1.1 Space Heat Gain

The space heat gain (instantaneous rate of heat gain) is defined as the rate at which heat enters into/or is generated within a space at a given instant of time and can be classified both according to the mode in which it enters the space (radiation, conduction, etc.) and whether it is a sensible or latent heat gain.

3.1.2 Space Cooling Load

Space cooling load is defined as the rate at which

heat must be removed from the space to maintain room air temperature at a constant value. It differs from the space heat gain defined above in that some of the heat gains (notably radiation) are partly absorbed by the building components and contents and do not appear in the room air until a later time.

3.1.3 Space Heat Extraction Rate

Space heat extraction rate is defined as the rate at which heat is moved from the conditioned space. It differs from the cooling load defined above since the cooling equipment capacity and controls determine the rate of heat extraction, which rarely exactly matches the cooling load. As a consequence, the space temperature rarely remains constant at its design value; rather, it fluctuates between the low and high limits of the control system. Proper simulation of the control system in the computation of the space heat extraction rate can result in predictions which are closer to the actual case than if the cooling load calculations are simply considered.

3.1.4. Cooling Coil Load

The cooling coil load is defined as the rate at which energy is removed at the cooling coil and includes the space heat extraction rate as well as any additional loads which occur outside the conditioned space (e.g., heat gain in distribution systems, outdoor air introduced by the cooling equipment, etc.).

3.2 Range of Energy Analysis Methods

The building energy analysis methods that have been developed and reported in the literature span a very wide range of sophistication. Many of the simpler

methods attempt to calculate only heat gain (or loss) and do so using a steady-state assumption, or at best the assumption of a series of repeatable daily fluctuations (air temperature, solar radiation, etc.). Translating the heat gains or losses to space cooling or heating loads and beyond these to HVAC equipment loads is beyond the scope of the simple methods. The main use of such methods is generally for the evaluation of peak or design loads so that equipment capacity can be selected. Such methods may also be of some limited use in the original design of the building envelope to assess the energy impact of various building component alternatives.

At the other extreme in terms of sophistication of method, there are a large number of detailed computer programs which deal with the various heat flow rates (space heat gain, space cooling load, space heat extraction rate and cooling coil load) as well as the modelling of a large variety of HVAC systems, control strategies, energy management schemes and energy recovery capabilities. Generally, appropriate economic packages to calculate payback periods, life cycle costing and cash flow tables are also a part of the larger sophisticated programs.

3.3 Description of Methods by Category

Although many users tend to classify energy analysis procedures as "hand methods" or "computer methods", the increasingly wide use of computers (ranging from main-frame to desk top sizes) has resulted in what were formerly considered "hand methods" being programmed for ease of use. Thus, a more realistic classification may be the ASHRAE scheme[2] which recognizes three classes:

- single measure methods
- simplified multiple-measure methods
- detailed simulation methods.

3.3.1 Single Measure Methods

Single measure methods assume that the energy required to maintain comfort depends on a single parameter: the outdoor dry-bulb temperature. Such single measure methods have been applied to both heating and cooling energy estimates, but the heating energy estimating methods are more developed and refined than the comparable cooling energy estimating methods.

In the past, the application of single-measure methods has generally been restricted to residences, although there have been and continue to be attempts to modify the procedures for application to some commercial or light industrial buildings.[3]

Degree-Day Method

The well known "degree-day method" for estimating heating requirements assumes that for outside temperatures above 18.3 C (65 F), the internal heat gains (including solar) offset heat losses and that consequently no energy is required for heating. Below 18.3 C, the amount of heating energy required is assumed to be directly proportional to the difference between the main daily temperature and 18.3 C. Although this method historically yielded reasonable predictions using the 18.3 C (65 F) base for degree-day calculations, the increasing amounts of insulation being used as well as the significantly increased internal gains from electrical appliances mean that the 18.3 C (65 F) base temperature is no longer a reflection of the balance point for many heated buildings. Some researchers[4] have chosen to modify the original degree-day formula with empirical factors in an attempt to obtain agreement between predictions and measured data. The reader is referred to Chapter 28, "Energy Estimating Methods", of the 1981 ASHRAE Handbook of Fundamentals[2] for the currently recommended form of the degree-day method and the relevant discussion regarding the empirical factors.

Other researchers[5] use a method in which the balance point of the building is calculated and the degree days below that balance-point temperature are used to compute the energy requirements. The method produced good results, according to a number of researchers[5-8]. Guntermann[3] also proposes the use of a balance point basis for evaluation of degree days in commercial and industrial buildings.

In order to overcome one of the problems caused by the simple degree-day method, namely the inability to account for "temperature swing" during the day, ASHRAE[2] recommends the development of procedures using either empirical "daily temperature swing" factors, or evaluation of degree days from actual hourly weather data (thus automatically accounting for temperature swings) rather than the current methods which use monthly mean temperatures.

Cooling Energy Estimates

The two single-measure methods for estimating cooling energy requirements are "The Equivalent Full Load Hours Method" and the "Cooling Degree Day Method".

The first method uses estimates (based on electric utility information) of the equivalent rated full load hours of operation for properly sized equipment during a normal cooling season and the power requirements of various pieces of equipment to arrive at a cooling energy estimate.

The second method uses tabulated cooling degree days in a manner similar to that described earlier for the heating degree-day method. It is pointed out that because of the additional complexities involved in a cooling as opposed to a heating calculation, "attempts to correlate cooling energy requirements against a single climate parameter have not been highly successful."[2]

3.3.2 Simplified Multiple-Measure Methods

One of the simplified multiple-measure methods is termed the "Bin Method". This method effectively involves making an energy calculation for a number of outdoor dry-bulb temperatures and applying a weighting factor to the calculations. The weighting factor is the number of hours of occurrence of each of the outdoor temperatures as grouped in "temperature bins". The method is applicable both to heating calculations and to cooling calculations, for which some additional data is utilized. This additional data involves the grouping of the temperature bin information in three daily 8-hour shifts as well as the mean coincident wet-bulb temperature data for each of the dry-bulb temperature bins.

Refinements of the bin method are possible and have been utilized[9,10]. The modified bin method was adapted from a method called REAP (Rational Energy Analysis Procedure) developed by the Carrier Corporation[11]. It differs in the calculation of the loads by using the Cooling Load Temperature Difference (CLTD) method which adjusts the temperature difference to an effective value which accounts for the thermal mass of the building components. Another improvement of the method involves the separation of the calculation into "occupied" and "unoccupied" periods, with corresponding implications regarding modelling of the HVAC system.

Kusuda[9] presented a comparison of this simplified method (known as the ASHRAE TC 4.7 procedure) with a number of more detailed analysis procedures for an office building. Although it is promoted as a simplified procedure, many of the participants in his study commented on the time-consuming, tedious nature of the calculations. They also complained about vagueness in the instructions for this simplified procedure.

Conclusions resulting from this comparison of detailed and simplified methods were as follows:

If used by the same analyst, results produced by both methods were similar. The differences that occurred were smaller than the differences produced by several analysts using different detailed programs to analyse the small office building.

For large and more complex buildings (large office buildings, hospitals, warehouses and department stores) the simplified method produced results similar to those produced by three detailed energy programs (BLAST, DOE-1, and AXCESS).

Another simplified energy analysis method which was the subject of recent research effort is a graphical technique[12]. Separate graphs are prepared for each of the three components of the overall energy calculation, namely, evaluation of the space load, determination of the secondary equipment load, and evaluation of the energy requirements of the primary equipment. These sets of graphs must also be prepared for each weather zone, each building type and size range, and type of HVAC system. To justify the considerable effort entailed in making the numerous calculations needed for preparing such graphs, the building types and sizes would have to be fairly common structures, widely used in practice. Otherwise, application of detailed computer methods which allow for diversity in building components, configurations, etc., would be a preferred alternative.

3.3.3 Detailed Simulation Methods

Detailed simulation methods usually involve energy calculations at frequent time steps (generally hourly) for complex buildings which have been modelled as a number of independent thermal zones. The calculations utilize models of the various elements of the HVAC system to attempt to follow their constantly changing response to the building loads and control system. Figure 1 (from Reference

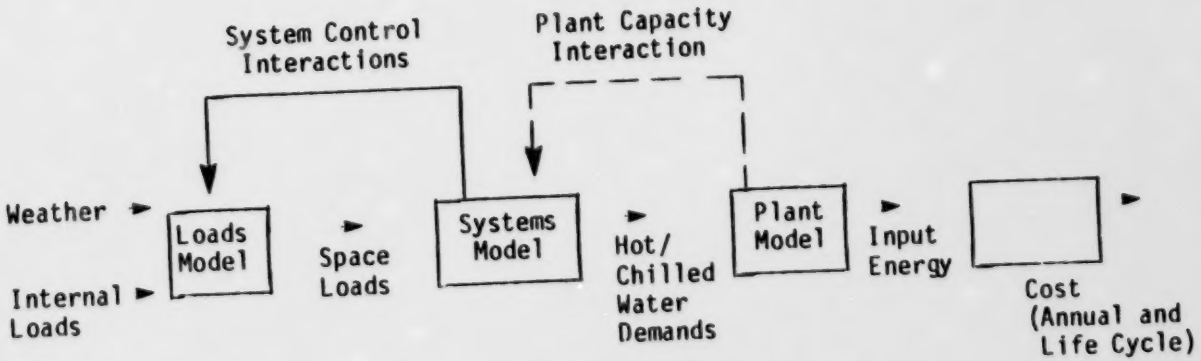

Fig. 1 Simplified Model for Detailed Simulation Method for Energy Estimation

Source: ASHRAE Handbook of Fundamentals
Ch. 28 Energy Estimating Methods

2) shows a schematic representation of most detailed simulation methods. Successive calculations are performed to evaluate the space loads, the air-conditioning delivery system, and the central plant equipment, followed by an economic evaluation.

The purpose of performing calculations at short time intervals is to attempt to adjust for the complex changes resulting from the balance between fluctuating internal and external loads and HVAC system response. In many instances the selection of hourly time intervals is a reflection of the fact that weather data (dry-bulb and wet-bulb temperature, wind and solar radiation) are available at hourly increments. For some applications, namely control system and HVAC system response, this hourly time increment is too coarse, and modelling should be performed on an even finer time base. However, the cost of simulation as well as other factors can also have a strong influence on the size of time steps for the calculations.

The calculations themselves can be very complex and are often iterative in nature. As an example, Figure 2 (from Reference 2) shows schematically the flow pattern of the calculations for the first component of the overall simulation method depicted in Figure 1, namely, the estimation of the space load.

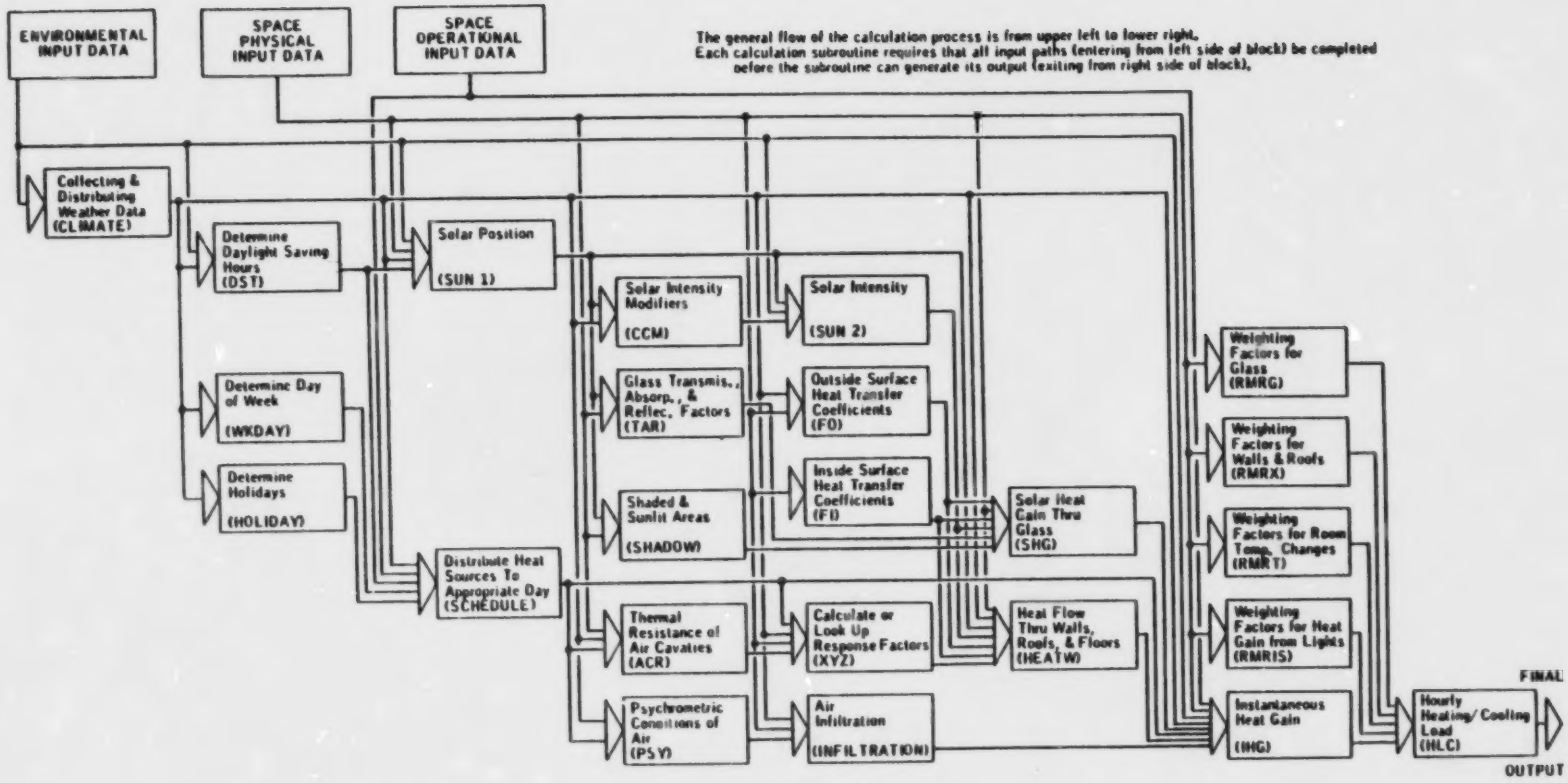
ENVIRONMENTAL INPUT DATA
SPACE PHYSICAL INPUT DATA
SPACE OPERATIONAL INPUT DATA
The general flow of the calculation process is from upper left to lower right. Each calculation subroutine requires that all input paths (entering from left side of block) be completed before the subroutine can generate its output (exiting from right side of block).
Collecting & Distributing Weather Data (CLIMATE)
Determine Daylight Saving Hours (DST)
Determine Day of Week (WKDAY)
Determine Holidays (HOLIDAY)
Solar Position (SUN 1)
Distribute Heat Sources To Appropriate Day (SCHEDULE)
Solar Intensity Modifiers (CCM)
Glass Transmis., Absorp., & Reflec. Factors (TAR)
Shaded & Sunlit Areas (SHADOW)
Thermal Resistance of Air Cavities (ACR)
Psychrometric Conditions of Air (PSY)
Solar Intensity (SUN 2)
Outside Surface Heat Transfer Coefficients (FO)
Inside Surface Heat Transfer Coefficients (FI)
Calculate or Look Up Response Factors (XYZ)
Air Infiltration (INFILTRATION)
Solar Heat Gain Thru Glass (SHG)
Heat Flow Thru Walls, Roofs, & Floors (HEATW)
Weighting Factors for Glass (RMRG)
Weighting Factors for Walls & Roofs (RMRX)
Weighting Factors for Room Temp. Changes (RMRT)
Weighting Factors for Heat Gain from Lights (RMRIS)
Instantaneous Heat Gain (IHG)
Hourly Heating/Cooling Load (HLC)
FINAL OUTPUT

FIGURE 2: Flow Diagram for Calculation of Hourly Heating-Cooling Load using ASHRAE Algorithms.

SOURCE: ASHRAE Handbook of Fundamentals Ch. 28 Energy Estimating Methods.

There are possibly a hundred or more detailed simulation methods, many of which have been reported in the literature. The range of programs is very wide, regardless of the method of classification (sophistication, availability, applicability, versatility, etc.). There are several published bibliographies of these computer programs[13-18]. In most cases, the number of programs was too extensive and the level of information required too detailed for the authors of the bibliographies to personally evaluate the programs. Thus, the information that is provided for each of the programs has usually been obtained from the program developer/originator. It is extremely difficult to obtain any type of comparative information regarding the use and quality of these programs by others, except for the half dozen or so programs which are widely available because of the support provided by a government agency (e.g., DOE) or because they can be used on a large time-sharing system, or both. If little is known about the flexibility, versatility and applicability of many of these programs, generally even less is known about their validation. Often, the potential user must accept the programmer's assertions that the computer code utilizes the most recent ASHRAE algorithms and that the collective assembly is correct.

4.1 ASHRAE Bibliographies

In 1975 ASHRAE published a bibliography[13] of available computer programs in the general area of heating, refrigerating, air conditioning and ventilating. This document was prepared for ASHRAE by the Battelle Columbus Laboratories. The objective was to inform potential program users what programs were available, what the programs were designed to do and to provide a contact person for each of the programs. Judgements as to the relative merits of the programs were not part of the information. Recently, a revised and updated version of this bibliography[14] was made available by ASHRAE.

4.2 PWC/EMR Bibliography

A bibliography[15] has recently been prepared by L. Jones of B.F.H. Shawinigan for the PWC/EMR program dealing with the "Review, Support and Development of Building Energy Analysis Tools". This preliminary bibliography (October 1981) has grouped the references into eleven different subject categories within which seven subclassifications are used, as indicated in Table 1. Although some of the literature citations are incomplete in the preliminary copy of the document available to the author, this bibliography represents a strong base upon which to build a publication for the dissemination of this information to users of building energy analysis tools.

4.3 EPRI Reference Manual

Another manual entitled "Building Energy Analysis Computer Programs with Solar Heating and Cooling System Capabilities", prepared for the Electric Power Research Institute by Arthur D. Little Inc.[16] in 1979, presents a fairly thorough evaluation of a large number of detailed simulation programs as well as information regarding a number of manual methods.Although the report title implies only programs with solar capabilities, the authors found that most sophisticated computer programs were also applicable to solar calculations and simulations. Therefore they included descriptions of these programs. In addition to brief descriptions of the programs and their accessibility, the authors have provided a bibliography of the most important literature references for each of the programs and an extensive set of summary matrices for the characteristics of thirty-one of the approximately seventy computer simulation models which were identified in the study. These summary matrices have been included as Appendix A.

Table 1

Classification of References

1. Simulation Programs - Description & Documentation *
2. Calculation & Simulation Procedures *
3. Weather Data
4. Field Testing of Algorithms & Programs *
5. Parametric & Sensitivity Studies *
6. Applications *
7. Review & Comparison of Programs *
8. Programming Techniques
9. Energy Analysis for Building Code Use
10. Simplified Calculation Procedures *
11. General & Miscellaneous

* For all these there are subsystems as described below:

(i) Energy Analysis
(ii) Load Estimation
(iii) Ductwork Systems
(iv) Pipework Systems
(v) Lighting Systems
(vi) Solar Heating
(vii) General & Miscellaneous

4.4 SERI Reports-Energy Analysis Methods

The Solar Energy Research Institute (SERI) has also prepared two documents[17,18] entitled:

> Analysis Methods for Solar Heating and Cooling Applications: Passive and Active Systems, 3rd Edition, Aug. 1980
>
> Microcomputer Methods for Solar Design and Analysis: Passive and Active Systems, 1st Edition, Feb. 1981

These documents contain summary matrices of the programs characteristics as well as brief program descriptions and contacts for each of the programs. The summary matrices from these two reports have been included as Appendix B. Although the microcomputer methods report covers new material, the material for the computer methods summary was based largely on the A.D. Little report for the Electric Power Research Institute discussed earlier.

The current situation regarding the energy analysis methods that are presently available can be addressed from a number of viewpoints. Recently, an ASHRAE-sponsored meeting[19] brought together nine highly regarded professionals active in the specific area of energy analyses. Much of the following discussion reflects this state-of-the-art assessment of energy analysis methods.

5.1 Load Calculations

Three new developments in the area of load calculations are the utilizaton of smaller time steps in the calculations to accommodate the modelling of controls, the modelling of entire buildings using multi-room models rather than one zone or one-room models, and the importance of daylighting and the interactions which occur in the lighting, heating and cooling computations.

Limitations in current models include the methods by which infiltration is handled, as well as underground heat transfer, which could be of importance if there is a move toward underground buildings.

A common point of concern deals with the matter of input information. In cases when input information is complete and without assumptions, agreement between predicted and actual building energy usage is normally very good. Since many programs might be utilized at a stage of design or construction when much of the input information cannot be accurately specified, the sophistication of most modelling techniques is more than adequate.

5.2 Systems Simulation

The rapid advances in the development of new

products and systems require that existing programs be continually revised to accommodate the latest technology. This area was considered to be one in which the greatest improvement could be made in programs.

5.3 Heat Recovery Energy Control Systems

Weaknesses in current programs are the modelling of cold and hot storage and the simulation of DX (Direct Expansion) coils in rooftop units, losses in supply and return ducts, etc.

5.4 Energy Management and Control Systems (EMCS)

Available computer programs which use hourly time steps in the calculations are unable to accurately simulate energy management control systems, which typically require time steps of minutes or seconds.

5.5 Solar Energy Systems

Although simulation methods for active solar systems appear to be well established, a comparable level of development does not exist for passive solar systems. Simulation methods for active solar systems exist, but there are discrepancies between design performance and actual field performance of systems. This is also a problem in other areas and is not specific to solar systems alone.

5.6 Microcomputers for Energy Analysis

Microcomputers will probably require simplified energy analysis methods in contrast to the comprehensive techniques of the detailed computer methods. Some degree of success has been achieved with a "variable based degree-day method" for residences, and this may also be the case for other building

categories where a single-zone building model is appropriate. Many warehouses are expected to fit this single-zone category. Efforts are needed to extend the simplified techniques for application to multi-zone buildings and complex HVAC systems.

There appears to be a big demand for simplified methods, or alternatively, simplified input and guidance in the use of the more sophisticated programs. Such programs are described as "user-friendly". The use of building energy analysis methods definitely appears to be increasing, and the application of microcomputers to the task should enhance this trend.

5.7 Role of Government Activities in Energy Analysis R and D

The involvement of governments in basic research in the development of energy analysis methods was considered appropriate, but direct competition in the marketing of detailed simulation programs was viewed as an inappropriate activity [19]. To put it even more finely, the development of algorithms is acceptable, but the production of a computer code is one step too far for government activities. Research areas currently in need of R and D beyond the capabilities of the private sector include infiltration, underground heat transfer, multi-zone models, interface between building components and systems, and moisture levels in rooms, including moisture absorption by furniture and surfaces.

In order for government-funded projects to be productive, industry should be involved in the identification of the problem areas and priorities. Such a development appears to have begun in Canada recently with a program by Public Works Canada sponsored by the Department of Energy, Mines and Resources. The initial steps in this program are outlined below.

A program of work for the "review, support and development of energy analysis tools" is currently underway. Public Works Canada with funding from Energy, Mines and Resources has formed a steering committee with representation from PWC, EMR and NRC (DBR) to guide this program of work.

In the first phase of the program designated the "review" stage, attempts are being made to contact industry to determine their needs. A questionnaire (see Appendix C) has been mailed to known and potential users of energy analysis methods. The responses from these questionnaires will serve as one source of the information guiding the direction of further phases of the program.

A second part of the "review" stage will consist of small discussion meetings held in a number of locations across Canada with interested industry users. To further the development of these talks, a discussion document (see Appendix D) was circulated with the questionnaire.

This discussion document not only highlights a significant number of perceived problems with present energy analysis methods but advances comments which suggest a course of action to remedy the problems.

Many of the problems presented in the discussion document have been discussed previously (need for multi-zone models, smaller time steps in order to simulate controls, etc.) but a number of other concerns have also been identified.

The scope of the above program covers all buildings (but more specifically buildings other than resi-

dential or "skin-sensitive" buildings); thus the program would obviously impinge on the warehouse and light industrial category. To avoid duplication of effort and to allow the efforts to be complementary to one another, the author has made initial contact with two of the members of the PWC Steering Committee. Further efforts will be made to co-operate in the identification of industry's needs and the provision of solutions in the form of appropriate energy analysis methods.

Although some of the replies to the questionnaire are still being received and the analysis of those received is still incomplete, a sufficiently large number of responses have been summarized to allow the identification of some of the major factors affecting the PWC/EMR study and the present WLIB study.[20]

The response from architectural firms indicates that a relatively small percentage is currently using computerized energy analysis methods. The likely reason for this is the unsuitability of current programs for use at the preliminary design stage.

Engineering firms that have used a detailed energy analysis method, such as the ESA (MERIWETHER) program, have a number of complaints regarding its use. Several users have indicated support for this same program, while others intend to use alternative programs such as DOE 2 or ESP. A significant number of consulting engineers have purchased the Carrier E20-II series of programs for use on the Radio Shack TRS-80 microcomputer. Although they have identified some limitations in the programs, they are apparently satisfied with this level of analysis. No other microcomputer hardware and/or software has received a comparable level of acceptance.

1. A survey of the literature[13-18] reveals that there are literally hundreds of computer programs and manual methods available for various aspects of building energy analysis. However, many of these do not fulfill some key requirements for the user, including access to the computer code, a high level of support, and documentation, etc. (see Appendix D for detailed comments).

2. There is a demand for simplified programs for application to non-residential buildings. Alternatively, sophisticated programs with "user-friendly" input routines could possibly fulfill much of this demand.

3. The use of building energy analysis methods is increasing significantly, and this trend is expected to be enhanced by the rapidly growing use of microcomputers for this application. There exists a need to provide, if not a validation of the many simplified methods being employed with microcomputers, at least an evaluation of the limits of applicability occasioned by the simplifying assumptions.

4. In all energy analysis methods ranging from the simple to the sophisticated, there are several parts of the load calculation which could benefit from additional research efforts, namely infiltration, underground heat transfer, multi-zone models, simulation of new HVAC systems and controls, and passive solar modelling, among others.

5. To make government efforts in the energy analysis research area most productive, the needs and priorities of industry must be taken into consideration. The current thrust of the Public Works Canada program on building energy analysis methods should be encouraged and supported. Where possible, joint efforts between the researchers of the present study and those from the PWC study should be undertaken.

6. The development of a single program which could be utilized at a variety of levels, beginning with the preliminary design phase and continuing through refined design stages and ultimately to the detailed engineering level, would be most desirable. Such a program would automatically circumvent a number of the problems which currently arise because several different (probably incompatible) programs must be used at the differing stages delineated above. The need to learn a multiplicity of program languages, job control systems, etc., would be eliminated. The user or users could be assured of consistency in input data at the various levels without costly duplication of effort. The co-operation of architects and engineers in a joint thrust to achieve an energy-efficient building and HVAC system design would be furthered by the development of such a program which would encompass the needs of both groups. Efforts to develop such a program are recommended.

1. ASHRAE Handbook 1981 Fundamentals, Chapter 26 "Air Conditioning Cooling Load" American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia.

2. ASHRAE Handbook 1981 Fundamentals, Chapter 28 "Energy Estimating Methods" American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia

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4. Reeves, G.A. "Degree-Day Correction Factors - Basis for Values", ASHRAE Transactions Vol. 87, Pt.1, 1981, p.504

5. Kusuda, T. Sud, I., Alereza, T. "Comparison of DOE-2 Generated Residential Design Energy Budgets With Those Calculated by the Degree-Day and Bin Methods", ASHRAE Transactions, Vol. 87,Pt.1, 1981

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14. Howell R.H. and Sauer, H.J.Jr. "Bibliography on Available Computer Programs in the General Area of Heating, Refrigerating, Air Conditioning and Ventilating" Second Edition, American Society of Heating, Refrigerating, and Air Conditioning Engineers, 1980.

15. Jones, L. "Document #3 Preliminary Bibliography-Computers for Building Architecture and Engineering Design" prepared for Department of Energy, Mines and Resources program "Review, Support and Development of Building Energy Analysis Tools" prepared by B.F.H. Shawinigan, October 1981.

16. Feldman, S.J. and Merriam, R.L. "Building Energy Analysis Computer Programs With Solar Heating and Cooling System Capabilities" prepared for Electric Power Research Institute (EPRI) prepared by Arther D. Little, Inc., August 1979, ER-1146.

17. Solar Energy Research Institute (SERI) "Analysis Methods for Solar Heating and Cooling Applications - Passive and Active Systems" 3rd Edition, August 1980.

18. Solar Energy Research Institute (SERI) "Microcomputer Method for Solar Design and Analysis - Passive and Active Systems" 1st edition, February 1981.

19. "Building Energy Analysis Methods - A Roundtable Discussion", ASHRAE Journal 23(6), 32-37, 1981.

20. Personal Communication, Les Jones, B.F.H. Shawinigan, Ottawa, Ontario, March, 1982.

Appendix A - Matrix Summaries - EPRI Reference Manual[16]

Appendix B - Matrix Summaries - SERI Reports[17,18]

Appendix C - Public Works Canada/Energy, Mines and Resources. Survey to Identify Current and Future Requirements for Software Support and Development for Energy Analysis and Energy Efficient Design.

Appendix D - Public Works Canada/Energy, Mines and Resources. Discussion Document re "Current Limitations and Future Possibilities for Energy Analysis Techniques".

APPENDIX A

Matrix Summaries - EPRI Reference Manual[16]

TABLE 3–1
HISTORY AND PROGRAM USES

Program Name	Sponsored By	Developed By	Maintained By	Date of Release		Building Load Analysis	HVAC Equipment Systems Analysis	Load Modified Systems Analysis	Economic Analysis	Active Solar Systems Analysis	Passive Solar Systems Analysis	Life Cycle Cost Analysis	Net Analysis	Cost of Supply Analysis	Comments	Summary Description Page No.
				Original	Current											
AXCESS	Edison Electric Institute	E E I & Soshyo Stevenson Value & Knecht	E E I & Sysko & Hennessey (nio Sys)	1972	1978		●	●	●	●		●				4-2
BLAST	Air Force, Army, GSA	USA CERL	USA Construction Engineers Research Laboratory	1977	1978	●	●	●	●	●		●	●			4-3
DEROB	NSF ERDA DOE	F. Arumi-Noe'	Univ. of Texas		1979	●					●					4-4
DOE-2	LASL, DOE	M. Roshko	LASL	1978	1978	●	●	●	●	●		●				4-5
ECUBE III	American Gas Association	Subcontractors	A.G.A.		1978	●	●		●		●	●			Active Solar Being Added	4-6
EMPES	Electric Power Research Instit.	Arthur D. Little, Inc.	Arthur D. Little, Inc.	1978	1978	●	●	●	●	●		●	●	●		4-7
ENERGY I	Gibson-Yackey-Trindade Associates	Robert Z. Gibson	Gibson Yackey Trindade Associates	1974	1978	●	●	●	●	●		●	●			4-8
E P.	Energy Management Services	EMS	EMS	1976	1978	●	●	●	●	●	●	●				4-9
ESAS	Ross F. Merriweather & Assoc., Inc.	Ross Merriweather	Ross Merriweather	1980	1978	●	●	●	●		●	●	●			4-10
ESP-1	Automated Procedures for Eng. Cons. (APEC)	Stone and Webster Eng. Corp.	APEC	1977	1978	●	●		●		●				Active Solar Being Added	4-11
F-CHART	U.S. DOE	Solar Energy Lab. U. of Wisconsin	Solar Energy Lab. U. of Wisconsin	1976	1978					●		●				4-12
FREHEAT	U.S. DOE	Colorado State University	Colorado State University	1978	1978						●	●				4-13
HACE	Wm. Tao & Associates, Inc.	WTA/Computer Services, Inc	WTA/CSI	1978	1978	●	●	●	●	●	●		●			4-14
HISPER	Marshall Space Flight Center	Marshall Space Flight Center	Marshall Space Flight Center	1978	1978					●						4-15
HSCAP	NASA	GARD, Inc	NASA @ Langley Res. Center	1974	1978	●	●		●	●		●	●			4-16

TABLE 3-1 (Cont.)

HISTORY AND PROGRAM USES

Program Name	Sponsored By	Developed By	Maintained By	Date of Release		Building Load Analysis	HVAC Equipment/ Systems Analysis	Load Managed Systems Analysis	Economic Analysis	Active Solar Systems Analysis	Passive Solar Systems Analysis	Economic Analysis	Rate Analysis	Cost of Supply Analysis	Comments	Summary Description Page No.
				Original	Current											
RSVP	U.S. Dept. of H.U.D.	Booz-Allen & Hamilton	Booz-Allen & Hamilton/ Franklin Institute	1977	1977					●		●			Based on F Chart	4-17
SCOUT	GARD, Inc.	GARD, Inc.	GARD, Inc.	1976	1978	●	●		●		●	●	●		Based on NECAP	4-18
SEE	NSF Grant The Singer Co.	W. S. Fleming & Assoc., Inc. The Singer Co. Syracuse U. & VVER	W.S. Fleming & Assoc., Inc. The Singer Co.	1976	1977	●	●	●	●	●	●	●	●			4-19
SHASP	U.S. DOE	University of Maryland	University of Maryland	1977	1978	●				●		●				4-20
SIMSHAC	ERDA	Dr. C.B. Winn & Dr. G.R. Johnson	Dr. C.B. Winn & Dr. G.R. Johnson	1973			●	●	●	●		●				4-21
SOLCOST	U.S. DOE	Martin Marietta	Martin Marietta	1976	1978					●		●				4-22
SOLOPT	Texas A&M University	Larry O. Degelman	Texas A&M University	1978	1978				●	●		●				4-23
SOLTES	U.S. DOE	Sandia Laboratories	Marlon Fewell	1978	1978		●	●	●	●						4-24
SUN	Berkely Solar Group	Berkeley Solar Group	Berkeley Solar Group	1975	1978					●						4-25
SYRSOL	ERDA NSF DOE	Dr. Manus Ucar Syracuse Univ.	Dr. Manus Ucar Syracuse Univ.	1976	1978	●	●		●	●	●					4-26
TRACE	The Trane Company	The Trane Company	Building Systems Group	1972	1978	●	●	●	●	●		●	●			4-27
TRNSYS	U.S. DOE	U. of Wisconsin Solar Energy Laboratory	U. of Wisconsin Solar Energy Laboratory	1974	1978	●	●	●	●	●					Passive Being Added	4-28
TWO-ZONE	Lawrence Berkeley Laboratory	A.H. Rosenfeld et. al.	A.H. Rosenfeld et. al.	1975	1977	●					●	●				4-29
UWENSOL	State of Washington	A.F. Emery	A.F. Emery	1978	1978	●			●		●					4-30
WATSUN II	National Research Council of Canada	M. Chandra-Shekar	M. Chandra-Shekar	1977	1978					●		●				4-31
WESTINGHOUSE PROGRAMS	Westinghouse Electric Corp.	Westinghouse Electric Corp.	Westinghouse Electric Corp. Engineering Services	1964	1978	●	●	●	●	●	●	●	●			4-32

TABLE 3-2
APPLICATIONS

Program Name	BUILDING TYPE						HVAC SYSTEM											
	One Zone		Multiple Zone				Non-Solar (Conventional)					Solar					Thermal Storage for Load Mgmt	
	Space Heat	Space Cool	Space Heat	Space Cool	Hot Water		Space Heat	Space Cool	Pool Heat	Process Heat	Hot Water	Space Heat	Space Cool	Pool Heat	Process Heat	Hot Water	Space Heat	Space Cool
AXCESS	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
BLAST	●	●	●	●	●	●	●				●	●			●	●	●	
DEROB	●	●	●	●							●	●						
DOE-2	●	●	●	●	●	●	●		●	●	●	●			●	●	●	
ECUBE III	●	●	●	●	●	●	●	●	●									
EMPSS	●	●			●	●	●			●	●	●			●	●	●	
ENERGY 1	●	●	●	●	●	●	●			●	●		●		●	●		
EP	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
ESAS	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
ESP-I	●	●	●	●	●	●	●		●									
F-CHART										●	●							
FREHEAT	●		●								●							
HACE	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
HISPER	●	●								●	●	●						
NECAP	●	●	●	●	●	●	●											●

TABLE 3-2 (Cont.)
APPLICATIONS

Program Name	BUILDING TYPE				HVAC SYSTEM													
	One Zone		Multiple Zone		Non-Solar (Conventional)					Solar					Thermal Storage for Load Mgmt			
	Space Heat	Space Cool	Space Heat	Space Cool	Hot Water	Space Heat	Space Cool	Pool Heat	Process Heat	Hot Water	Space Heat	Space Cool	Pool Heat	Process Heat	Hot Water	Space Heat	Space Cool	
RSVP					●	●				●	●							
SCOUT	●	●	●	●	●	●	●	●	●									
SEE	●	●	●	●	●	●	●			●	●	●			●	●	●	
SHASP	●	●								●	●	●						
SIMSHAC	●	●			●	●	●	●		●	●		●		●	●		
SOLCOST	●	●								●	●							
SOLOPT	●									●	●							
SOLTES									●	●	●	●	●	●	●	●	●	
SUN	●					●					●							
SYRSOL	●	●	●	●	●	●	●	●		●	●							
TRACE	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
TRNSYS	●	●			●	●	●			●	●	●			●	●		
TWO-ZONE	●	●					●				●	●						
UMEASOL	●	●	●	●		●	●											
WATSUN II	●				●	●				●	●							
WESTINGHOUSE PROGRAMS	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	

TABLE 3-3

PROGRAM CHARACTERISTICS

Program Name	Program Type			Model Approach		Calculation Interval				Weather Data				
	Simplified Design	Detailed Simulation	Fixed Schedule	Component Based	Bin	Hour	Month	Year	Hour/Year	Supplied by User	Internally Generated	Hour	Month	Year
AXCESS		●	●			●			8760	●		●		
BLAST		●	●			●			8760	●		●		
DEROB		●	●			●			8760	●		●		
DOE-2		●		●*		●			8760	●	●	●		
ECUBE III		●	●			●			8760	●	●	●		
EMPSS		●	●			●			8760	●		●		
ENERGY 1		●	●			●			288	●	●	●		
E.P.		●	●			●			8760	●	●	●		
ESAS		●	●			●			8760	●		●		
ESP-1		●	●			●			8760	●		●		
F-CHART	●		●				●			●	●		●	
FREHEAT		●	●			●	●		8760		●	●		
HACE		●	●			●			8760	●		●		
HISPER		●	●			●			8760	●		●		
NECAP		●	●			●			8760	●	●	●		

* DOE-2 Solar Simulation

TABLE 3–3 (Cont.)
PROGRAM CHARACTERISTICS

Program Name	Program Type		Model Approach			Calculation Interval				Weather Data					
	Simplified Design	Detailed Simulation	Fixed Subroutine	Component Based	Sun	Hour	Month	Year	Hour/Year	Supplied by User	Internally Generated	Hour	Month	Year
RSVP	●		●				●			●	●		●	
SCOUT		●	●			●			8760	●		●		
SEE		●	●			●			3016		●	●		
SHASP		●	●			●			8760	●		●		
SIMSHAC		●		●		●			8760	●		●		
SOLCOST	●		●				●			●	●		●	
SOLOPT		●	●			●			8760		●		●	
SOLTES		●		●	●	●			8760	●		●		
SUN	●		●				●			●			●	
SYRSOL		●	●			●			8760		●	●		
TRACE		●	●			●			1152*	●	●	●		
TRNSYS		●		●		●			8760	●		●		
TWO-ZONE		●	●			●			8760	●	●	●		
URWINSOL		●	●			●			8760	●		●		
WATSUN–II		●	●			●			8760	●		●		
WESTINGHOUSE PROGRAMS		●	●			●			8760		●	●		

*Trace Solar carries out calculations for 8760 Hours/Year.

TABLE 3-4

AVAILABILITY, DOCUMENTATION AND COMPUTER RELATED CHARACTERISTICS

	AVAILABILITY						LEVEL OF DOCUMENTATION					COMPUTER RELATED CHARACTERISTICS				
	Program Deck	Manual	Time Share	Lease	Book	Comments	User's Manual	Program Manual	Source Code	Reference	Training Necessary (Yes/No)	Program Language	Program Developed on	Power / Mode of Access	Approximate Number of Card Images	Core Required
AACESS	●					As a service by Elect Utilities & Access Regional Consultants	●	●	●	1-5	●	FORTRAN	IBM 360 IBM 370	Batch		282 K
BLAST	●	●					●	●	●	8-14		FORTRAN	CDC 7600	Batch	71,000	126 K
DEROB	●						●	●	●	16-18		FORTRAN	CDC 6600	Batch Interactive		77 K
DOE-2	●	●					●	●	●	19-23		FORTRAN	CDC 6600	Batch	11,000	120 K
ECUBE III		●		●			●	●		24	No Source	FORTRAN	CYBERNET	Batch		
EMPSE	●			●			●	●	●	25-27		FORTRAN	IBM 370	Batch	6,000	310 K
ENERGY I	●			●		Agreement with Gibson Yackey Trimble/Assoc	●			-		BASIC	Wang 2200B	Interactive		20 K
EP		●		●			●	●		28-30	●	FORTRAN	CDC	Batch Interactive	10,000	600 K Bytes
ESAS		●	●	●			●			31,32		FORTRAN	IBM 370	Batch Interactive	15,000	300 K (Max.)
ESP-1	●	●	●				●	●	●	34,37	●	FORTRAN	IBM 370/ 168 OSVS	Batch	30,000	360 K
F-CHART	●	●					●		●	38-43		FORTRAN	UNIVAC 110	Interactive	3,000	32 K
FREHEAT	●							●	●	-		FORTRAN	CYBER 172	Batch	2,000	61 K
HACE		●	●	●		WTA/CSI will process job with user	●			-		FORTRAN	IBM 370/ Digital Equip Corp PDP11	Batch *	4,000	IBM 180 K Bytes Dec 32 K Words
HISPER						Available at no cost upon request	●		●	44,45		FORTRAN	UNIVAC 1108	Batch	800	15 K
NECAP	●						●	●	●	50		FORTRAN	CDC	Batch		80 K

*K = 1024 Octal

AVAILABILITY, DOCUMENTATION AND COMPUTER RELATED CHARACTERISTICS

	AVAILABILITY					LEVEL OF DOCUMENTATION					COMPUTER RELATED CHARACTERISTICS				
Program Name	Purchase	Time Share	Lease	Batch	Comments	User's Manual	Program Manual	Sample Cases	Reference	Training Necessary (Where)	Program Language	Program Developed on	Primary Mode of Access	Approximate Number of Card Images	Core Required
REVP	●	●				●	●	●	66, 67		FORTRAN	UNIVAC 1108	Interactive	4,000	36 K K Words
SCOUT	●	●	●	●		●	●	●	68		FORTRAN	IBM CDC	Batch Batch	5,000 5,000	100 - 300 Bytes 50 - 200 Words
SEE				●	Through the Singer Co.	●			69 71		FORTRAN COBOL	IBM 370/165	Batch	6,500	800 K
SHASP				●	No cost to obtain	●		●	70		FORTRAN	UNIVAC 1108 40	Batch Interactive	650	
SIMSMAC	●								36		FORTRAN	CDC 6603	Batch	5,000	77 K
SOLCOST	●	●				●	●	●	70 66		FORTRAN	CDC	Batch/ Interactive	4,000	60 K Octal
SOLOPT	●					●		●	60,61		FORTRAN	AMDAHL 470 V/6	Batch	1,733	130 K Bytes
SOLTES	●				Available through Augusta in Spring 1978	●		●	67		FORTRAN	CDC 6600	Batch	10,000	Modular 30 - 140 K
SUN		●		●	Consulting agreement w/Berkeley Solar Group				-		FORTRAN	CDC 6400	Batch Interactive	2,000	40 K Bytes
SYRSOL					Commercially available but not actively marketed	●		●	103 - 110		FORTRAN	IBM 370	Batch	2,000	220 K
TRACE		●		●		●			-	No reported	FORTRAN	IBM 370/168	Batch		300 K
TRNSYS	●					●	●		111 - 121		FORTRAN	UNIVAC 1110	Batch	7,000	64 K Words
TWO-ZONE	●			●		●			122 - 124		FORTRAN	CDC 6600	Batch		126 K Octal
UNENSOL	●					●		●	125		FORTRAN	CDC 6400	Batch	2,400 - 4,000	100 K Octal
WATSUN II	●					●	●	●	127 - 129		FORTRAN	IBM 360/370	Batch	1,500	250 K
WESTING HOUSE PROGRAMS				●	Available from Westinghouse Engineering Services	●			130		FORTRAN	IBM 370/165	Batch	Load - 4500 Energy - 8500	Load - 230 K Energy - 700 K

TABLE 3-5a
BUILDING HEATING AND COOLING LOADS

Program Name	MATHEMATICAL MODEL						INTERNAL LOADS					INFILTRATION				VENTILATION			
	Steady State	Response Factor	Finite Difference or Differential Equation	Degree Day	CLTD or TETD	Sensible	Latent	Equipment	Time Dep. Loads	Built-In	Fixed	Variable	Built-In	User Specified	Fixed	Variable	Built-In	User Specified
AXCESS		●				●	●	●	●		●			●	●	●		●
BLAST		●				●	●	●	●			●		●		●		●
DEROB			●			●			●					●		●		●
DOE-2	●	●		●		●	●	●	●			●		●		●		●
ECUBE III		●				●	●	●	●			●		●		●		●
EMPSS			●			●	●	●	●			●		●		●		●
ENERGY 1					●	●	●	●	●		●			●	●	●		●
E.P.		●				●	●	●	●		●			●	●	●	●	●
ESAS			●		●	●	●	●	●			●		●		●		●
ESP-I		●				●	●	●	●					●				●
F-CHART				●		●												
FREHEAT			●			●		●	●	●		●				●		
HACE		●				●	●	●	●			●		●		●		●
HISPER				●		●					●			●				
NECAP		●				●	●	●	●			●		●		●		●

TABLE 3–8a (Cont.)
BUILDING HEATING AND COOLING LOADS

		MATHEMATICAL MODEL						INTERNAL LOADS					INFILTRATION				VENTILATION			
Program Name	Double Skin	Response Factor	Finite Difference or Differential Equation	Degree Day	CLTD or TETD	Steady	Lights	Occupants	Time Dep. Loads	Built In	Fixed	Variable	Built In	User Specified	Fixed	Variable	Built In	User Specified
RSVP				●		●												
SCRAT		●				●	●	●	●			●		●		●		●
SEE		●	●			●	●	●	●	●			●	●			●	●
SHASP		●				●	●	●				●		●		●		●
SIMSMAC			●			●			●			●		●		●		●
SOLCOST			●	●							●			●				
SOLOPT																		
SOLTES																		
SUN				●		●		●										
SYRSOL	●					●	●	●	●			●		●		●		●
TRACE					● TETD	●	●	●	●			●		●		●		●
TRNSYS		●		●		●		●	●		●			●				
TWO-ZONE		●	●			●	●		●	●		●	●			●	●	
URBENSOL			●			●	●	●	●			●		●		●		●
WATSUN-II	●					●			●									
WESTINGHOUSE PROGRAMS		●				●	●	●	●			●		●		●		●

TABLE 3–5b
BUILDING HEATING AND COOLING LOADS

Program Name	Building Envelope Studies	SOLAR GAINS						LOAD CONSIDERATIONS	
		INSTANT GAIN		TIME LAG		SOL-AIR			
		Thru Conduction	Thru Roof & Walls	Thru Conduction	Thru Roof & Walls	Thru Conduction	Thru Roof & Walls	Night Sky Cool	Space Temperature Float
ARCESS		●			●		●	●	
BLAST	●			●	●			●	●
DEROS	●			●	●			●	●
DOE-2	●			●	●			●	●
SCUBE III	●			●	●			●	●
SHPSS				●	●			●	●
SHSNGY 1	●	●			●			●	●
ESP	●			●	●	●	●	●	●
SSAS	●			●	●			●	●
ESP-1	●			●	●			●	●
F-CHART									
PREHEAT		●			●			●	●
NACE	●	●			●			●	
HSPSR			●				●		
NECAP	●			●	●			●	●

TABLE 3-6b (Cont.)
BUILDING HEATING AND COOLING LOADS

Program Name	Building Envelope Loads	SOLAR GAINS							LOAD CONSIDERATIONS	
		INSTANT GAIN		TIME LAG		SOL-AIR				
		Thru Fenestration	Thru Roof & Walls	Thru Fenestration	Thru Roof & Walls	Thru Fenestration	Thru Roof & Walls	Night Sky Cool	Space Temperature Float
RSVP									
SCOUT	●				●	●		●	●
SEE	●			●	●	●	●	●	●
SHASP	●			●	●		●		
SIMSHAC		●				●		●	●
SOLCOST				●	●				
SOLOPT									
SOLTES									
SUN	●	●			●			●	●
SYRSOL	●	●					●	●	●
TRACE	●	●			●	●	●	●	●
TRNSYS		●	●		●		●	●	●
TWO-ZONE	●			●			●	●	●
URMSOL	●	●	●					●	●
WATSUN-II		●	●						
WESTING-HOUSE PROGRAMS	●	●			●			●	●

TABLE 3-4
PASSIVE SYSTEMS

Program Name	Direct Gain	Trombe Wall	Water Wall	Roof Pond	Thermal Diode	Attached Sun Room	Phase Change Energy Storage	Ondyne and Overhangs	Heat Pipe	Natural Ventilation	Evaporative Cooling	Thermal Siphon	Other	Comments
ARCESS														
BLAST	●													
DEROB	●	●	●	●		●		●		●				Earth-Air Heat Exchanger
DOE-2	●													
ECUBS III	●		●			●		●						
EMPSS										●				
ENERGY 1														
E P	●							●			●		●	Light Switching and Drape Drawing on Solar Insolation
ESAS	●							●		●	●			Drape Drawing of Solar Insolation
ESP-I	●							●					●	Drape Drawing of Solar Insolation
F-CHART														
FREHEAT	●	●	●			●	●	●	●	●		●		
HACE	●		●					●	●					
HISPER														
NECAP	●					●		●						

TABLE 3-4 (Cont.)
PASSIVE SYSTEMS

Program Name	Direct Gain	Trombe Wall	Water Wall	Roof Pond	Thermal Shutter	Insulated Roof Panel	Phase Change Energy Storage	Rock Bed Storage	Heat Pipe	Natural Ventilation	Conservation Control	Thermal Radiator	Other	Comments
RSVP														
SCOUT	●	●				●		●						
SEE	●	●	●	●		●								
SHASP														
SHASHAC														
SOLCOST														
SOLOPT														
SOLTES														
SUN	●							●						
SYRSOL	●							●		●	●	●		
TRACE	●													
TRNSYS														
TWO-ZON	●					●		●		●	●			
UNIMOD	●	●	●	●		●		●		●				
WATSUN-II														
WESTING-HOUSE PROGRAMS	●	●	●	●		●	●	●	●	●	●	●		

TABLE 3-7a
ACTIVE SOLAR SYSTEM

Program Name	COLLECTOR TYPE					COLLECTOR ORIENTATION			COLLECTOR WORKING FLUID	
	Flat Plate	Reflector	Evacuated Tube	Focusing	Other	Stationary	Hourly Tracking	Seasonal Adjustment	Air	Liquid
AXCESS	●					●	●			●
BLAST	●		●			●				●
DEROB										
DOE-2	●		●	●		●	●		●	●
ECUBE III										
EMPSS	●		●			●	●			●
ENERGY 1	●	●	●	●		●	●			●
E.P.	●					●			●	●
ESAS										
ESP-1										
F-CHART	●					●			●	●
PREHEAT										
HACS	●	●	●	●		●	●	●	●	●
HISPER	●					●			●	●
HECAP	●					●				●

TABLE 3–7a (Cont.)
ACTIVE SOLAR SYSTEM

Program Name	COLLECTOR TYPE					COLLECTOR ORIENTATION			COLLECTOR WORKING FLUID	
	Flat Plate	Reflector	Evacuated Tube	Focusing	Other	Stationary	Hourly Tracking	Seasonal Adjustment	Air	Liquid
RSVP	●					●			●	●
SCOUT										
SES	●	●		●		●	●	●		●
SHASP	●		●			●				●
SIMSHAC	●	●	●	●		●			●	●
SOLCOST	●	●	●	●	●	●	●	●	●	●
SOLOPT	●		●	●		●	●			●
SOLTES	●	●	●	●		●	●	●		●
SUN	●					●				●
SYRSOL	●			●	●	●	●			●
TRACE	●	●	●	●		●	●	●	●	●
TRNSYS	●					●			●	●
TWO ZONE										
UWMSOL										
WATSUN-II	●		●		●	●			●	●
WESTINGHOUSE PROGRAMS	●	●	●	●	●	●	●	●	●	●

TABLE 3-7b
ACTIVE SOLAR SYSTEMS

Program Name	SOLAR COOLING SYSTEM			HEATING/COOLING COMPONENT MODEL		HEAT PUMPS			STORAGE MEDIUM				
	Rankine	Absorption	Desiccant	Based on Curves	Based on Heat Balances	Conventional	Solar	Both	Fluid	Phase Change	Chemical	Enclosed Liquid	Multiple Energy
AXCESS		●		●		●	●		●				●
BLAST		●		●		●	●		●				
DEROB													
DOE-2		●		●		●	●	●	●				●
ECUBE III													
EMPRS	●	●	●	●		●	●		●			●	
ENERGY 1						●	●		●				
E.P		●		●		●	●	●	●				
ESAS													
ESP-1													
F-CHART			●					●	●				
FRESHEAT													
HACE		●		●	●	●		●	●	●			
HISPER		●		●	●			●	●				
NECAP		●		●		●			●				

TABLE 3–7b (Cont.)
ACTIVE SOLAR SYSTEMS

Program Name	SOLAR COOLING SYSTEM			HEATING/COOLING COMPONENT MODEL		HEAT PUMPS		STORAGE MEDIUM					
	Rankine	Absorption	Dessicant	Based on Curves	Based on Heat Balances	Compressional	Solar	Rock	Fluid	Phase Change	Chemical	Enclosed Liquid	Isolated Energy
RSVP								●	●				
SCOUT						●							
SEE		●		●		●	●		●				
SHARP	●	●		●					●				
SIMBAC		●		●		●	●	●	●	●		●	
SOLCOST		●		●				●	●				
SOLOPT					●	●			●				
SOLTES	●	●		●				●	●	●		●	●
SUN					●				●				
SYRSOL	●			●		●	●		●				
TRACE		●		●		●	●	●	●			●	●
TRNSYS		●		●	●	●	●	●	●			●	●
TWO-ZONE													
UMENSOL													
WATSUN II				●		●	●	●	●				●
WESTINGHOUSE PROGRAMS	●	●	●	●	●	●	●	●	●	●	●	●	●

TABLE 3-4

CONVENTIONAL HVAC SYSTEMS AND EQUIPMENT

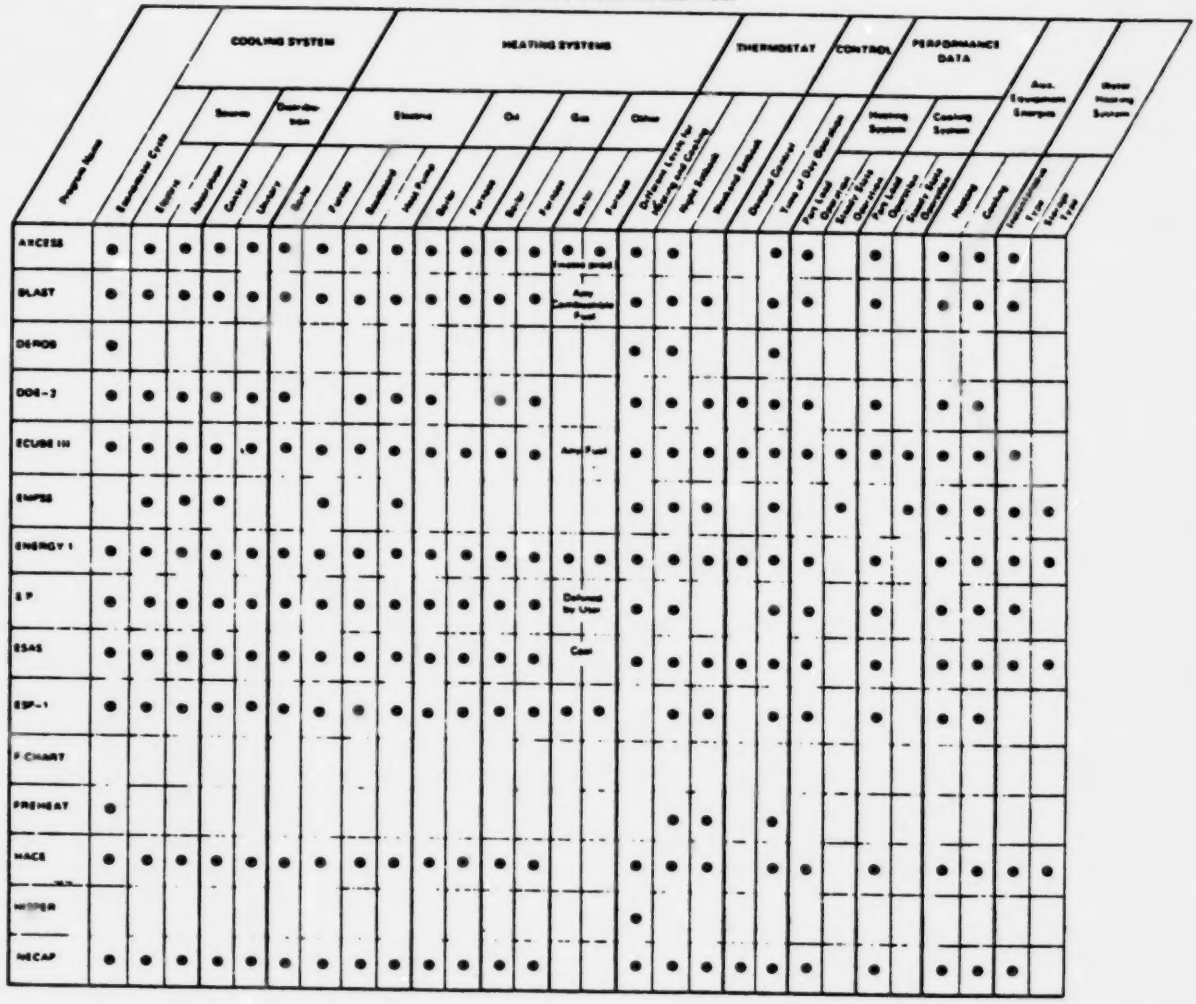

TABLE 3-8 (Cont.)
CONVENTIONAL HVAC SYSTEMS AND EQUIPMENT

Program Name	Economizer Cycle	Cooling System: Electric	Cooling System: Reciprocating	Cooling System: Centrifugal	Cooling System: Absorption	Heating System: Electric Boiler	Heating System: Electric Furnace	Heating System: Electric Baseboard	Heating System: Heat Pump	Heating System: Oil Boiler	Heating System: Oil Furnace	Heating System: Gas Boiler	Heating System: Gas Furnace	Heating System: Other Boiler	Heating System: Other Furnace	Heating System: Distance Limits for Heating and Cooling	Heating System: Height Limitation	Thermostat: Mechanical Switch	Thermostat: Electronic Control	Control: Time of Day Operation	Control: Part Load Operation Variable Speed	Control: Part Load Operation Staged	Performance Data: Heating Systems: Part Load Operation	Performance Data: Heating Systems: Staged Operation	Performance Data: Cooling Systems: Part Load Operation	Performance Data: Cooling Systems: Staged Operation	Heating Equipment: Time Constant	Heating Equipment: Start-up Time	Water Heating System
RSVP																													
SCOUT	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●		●	●	●	●	●	●	●	●		
SEE	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●	●			●		●	●	●	●	●
SHASP		●		●													●	●			●			●	●	●			●
SHEMAC	●		●			●	●	●	●	●	●	●	●				●	●	●	●			●			●	●	●	●
SIM COST							●	●				●		●	COAL						●			●	●	●			●
SOLOPT	●						●			●		●		●					●	●		●			●				●
SOLTES				●								●		●		●			●	●	●	●		●	●	●	●	●	●
SUN																													
SYSCOL	●	●		●		●				●							●	●		●					●	●	●	●	●
TRACE	●	●	●	●	●	●	●	●	●	●	●	●	●	COAL			●	●	●	●			●		●	●	●	●	●
TRNSYS				●	●			●	●	●		●		●			●	●			●			●	●	●			●	●
TWO ZONE	●						●										●	●		●									
UWENGCL	●	●															●	●	●	●	●								
WATSUN-H							●			●		●		●												●		●	
WESTING-HOUSE PROGRAMS	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●			●		●	●	●	●	●

TABLE 3-9
OUTPUT DATA

Program Name	BUILDING HEATING AND COOLING LOADS					BUILDING ENERGY USE							
	Daily	Monthly	Annual	Average Day Profile	Peak Day Profile	Daily	Monthly	Annual	Average Daily Profile	Peak Day Profile	Energy Use Breakdown Among Components	Auxiliary Energies	Life Cycle Costs
AXCESS	●	●	●		●	●	●	●		●	●	●	●
BLAST	●	●	●		●	●	●	●		●	●	●	●
DEROB	●	●	●		●	●	●	●	●	●	●		
DOE-2	●	●	●		●	●	●	●		●	●	●	●
ECUBE III	●	●	●			●	●	●			●		●
EMPSS		●	●				●	●	●	●	●	●	●
ENERGY 1		●	●		●		●	●		●	●	●	●
E.P.	●	●	●		●	●	●	●		●	●	●	●
ESAS		●	●		●		●	●		●	●	●	●
ESP-1	●	●	●			●	●	●			●	●	
F-CHART		●	●										●
PREHEAT	●	●	●	●									●
HACE					●					●	●	●	
HISPER	●	●	●								●		
NECAP	●	●	●		●	●	●	●		●	●	●	●

TABLE 3-9 (Cont.)
OUTPUT DATA

Program Name	BUILDING HEATING AND COOLING LOADS					BUILDING ENERGY USE							
	Daily	Monthly	Annual	Average Day Profile	Peak Day Profile	Daily	Monthly	Annual	Average Day Profile	Peak Day Profile	Energy Use Breakdown Among Components	Auxiliary Energies	Life Cycle Costs
RSVP		●	●										●
SCOUT	●	●	●		●	●	●	●		●	●	●	●
SEE	●	●	●			●	●	●	●		●	●	●
SHASP	●	●	●	●		●	●	●	●		●		●
SIMSHAC	●	●	●			●	●	●				●	●
SOLCOST		●	●				●	●					●
SOLOPT	●	●	●								●		●
SOLTES											●	●	
SUN		●	●	●							●		
SYRSOL	●	●	●			●	●	●			●	●	
TRACE		●	●	●	●		●	●	●	●	●	●	●
TRNSYS	●	●	●	●		●	●	●	●		●		
TWO-ZONE	●	●	●								●		●
UWENSOL	●		●	●							●		
WATSUN-H	●	●	●			●	●	●			●	●	●
WESTINGHOUSE PROGRAMS	●	●	●	●	●	●	●	●	●	●	●	●	●

TABLE 3–10
UTILITY RELATED DATA

Program Name	RATES						METERING			
	Energy	Demand	Time of Day	Fuel Adjustment	Ratchet	Time	Separate Meters for Customer Load	Separate Meters for Cust/Ut. Prod. Use	Single Meter for Combined Energy Use	Separate Meters for Customer End Use
AXCESS							●	●	●	●
BLAST	●	●					●		●	●
DEROB							●			
DOE-2	●						●			
ECUBE III							●		●	
EMPSS	●	●	●	●		●				●
ENERGY 1	●	●	●	●					●	
E.P.							●	●	●	●
ESAS	●	●	●	●	●	●	●	●	●	●
ESP-1	●	●							●	●
F-CHART	●									
PREHEAT	●									
HACB	●	●	●	●	●	●	●		●	●
HISPER										
NECAP	●	●								

TABLE 3–10 (Cont.)

UTILITY RELATED DATA

	RATES						METERING			
REVP	•									
SCOUT	•	•					•		•	•
545	•	•	•	•	•	•			•	
SHASP										
SHSHAC	•	•							•	
SOLCOST	•	•								
SOLOPT	•								•	
SOLTES										
SUN										
SYMBOL	•						•		•	
TRACE	•	•	•	•	•	•	•	•	•	•
TRNSYS									•	
TWO-ZONE	•	•							•	
UWENSOL										
WATSUN-II	•								•	
WESTING-HOUSE PROGRAMS	•	•	•	•	•	•	•	•	•	•

GLOSSARY

Selected headings used in the previous summary matrixes are presented below to provide amplification of the data in the Tables.

- Table 3-1: HVAC Equipment/System Analysis implies the ability to examine the tradeoffs among alternative systems. "Load Managed Systems" are those systems whose use is intended to shape the building's load profile in a particular fashion. Included are such thermal energy storage devices as an ice-maker, non-pressurized or pressurized water, ground heat storage, brick (ceramic) storage and chemical storage. "Controls Analysis" includes various space temperature control techniques, such as night setback as well as control of HVAC equipment via demand limiting and time-of-day operation. It may also refer to solar collector pump controls.

- Table 3-2: "Thermal Storage for Load Management" - if the program can simulate load managed systems, then for which functions can it be applied - hot water, space heating or space cooling (cold storage).

- Table 3-3: A discussion of program types and model approaches is given in Section 2. "Calculation Interval" designates the resolution (time-steps) in the program computations. "Weather Data": "Supplied by User" indicates tape or card input; "Internally Generated" indicates the weather data are stored in program files that the user indicates the geographic area in the data input to the program; "Hour, Month, Year" indicates minimum time resolution required in the weather data.

- Table 3-4: Availability by "Batch" indicates that the actual processing of the input data is carried out by the program supplier. The "user's Manual" tells how to prepare the input data and how to access the computer. A "Program Manual" describes the analytical bases for the model and may include the specific algorithms.

- Table 3-5a: "Steady State" loads are those which are either directly related to the difference between the outside and inside air temperatures or are read into the program as input data. "The Response Factor" method, "CLTD" (Cooling Load Timing of Day) and "TETD" (Time Equivalent Temperatures Differ) methods take into account the effects of building thermal mass on hourly loads. A detailed description of the methods is given in the ASHRAE Handbook of Fundamentals (1972, 1977).

- Table 3-5b: "Instant Gain" implies that the solar heat adds to the cooling load or reduces the heating load with no time-delay. "Time-Lag" of solar gains through fenestration implies that solar heat is first absorbed by building interior mass and then released to internal air by convection. "Sol-Air" method indicates that the solar gain made equivalent to an increased outside air temperature. "Night Shut-Off" indicates that the loads portion of the program recognizes that certain equipment may be shut down during periods of a day. "Space Temperature Float" indicates that the internal space temperature varies according to the load and HVAC system operation and may be outside of the thermostat dead band if the system capacity is exceeded by load.

- Table 3-6: "Direct Gain" implies ability to handle exterior (or interior) shading. "Trombe Wall" may or may not include air vents. "Thermic Diode" allows heat transfer in only one direction. "Drapes and Overhangs" imply the ability to actively control solar gains. "Natural Ventilation" implies that the air exchange rate is depended on outside temperature as well as wind speed. "Thermo-Syphon" indicates natural circulation solar collector for space heating.

- Table 3-7b: "Solar Assisted Heat Pump" designates the series arrangement whereby collected solar heat is used as a source for the heat pump.

- Table 3-8: "Part Load" operation implies that ability to predict effects of cycling on system COP in addition to accounting for the fraction of the hour the system is activated. "Auxiliary Equipment Energies" refers to energies used by pumps, fans and controls.

APPENDIX B

Matrix Summaries - SERI Reports[17,18]

SHAC Manual Design Methods Summary

The following table describes solar heating and cooling manual design methods. This table does not give all of the design methods applicable to SHAC analysis, but it does contain the most currently used and best known methods. These methods do not require access to a computer although some (e.g., F- CHART) have been implemented on computers. They vary in degree of sophistication from the simple, almost rule-of-thumb type to methods requiring programmable calculators. Some of the latter type methods are available from the source indicated as prerecorded programs on magnetic cards.

Description	Author	Availability			Applications: Active				Applications: Passive						Tools Required					Output			
		Cost ($)	Date	Reference/Source	Space Heating	Domestic Hot Water	Liquid Collector	Air Collector	Direct Gain	Thermal Storage Wall	Attached Sunspace	Thermal Storage Roof	Convective Loop	Tables Graphs	F Chart Type Calculation	Simulation	Programmable Calculator		Solar Fraction	Optimum Area	Economic Analysis	Other
A Simplified Method for Calculating Solar Collector Array Size for Space Heating	J D Balcomb J C Hedstrom		1976	Sharing the Sun Solar Technology in the Seventies Vol 4 American Section International Solar Energy Society 1976 pp 281-284	•	•	•	•							•	•					•		
Passive Solar Design Handbook SLR Method	J D Balcomb Bruce Anderson	14	1980	NTIS 5285 Port Royal Road Springfield VA 22161					•	•	△				•	•				•	•	•	
Predicting the performance of Solar Energy Systems	U S Army Construction Engineering Research Lab		1977	Rept No AD A035 608 9 ST (NTIS)	•	•	•	•							•	•				•	•	•	
Copper Brass Bronze Design Handbook – Solar Energy Systems	Copper Development Association	3	1978	Copper Development Association Inc 1011 High Ridge Road Stamford CN 06905	•		•	•							•	•				•			
Copper Brass Bronze Technical Report How to Design and Build a Swimming Pool Heater	Copper Development Association	Free	1976	Copper Development Association Inc			•								•	•				•		•	
PEGFIX and PEGFLOAT	W Glenne	75 both	1978	Princeton Energy Group 728 Alexander Road Princeton NJ 08540 (609) 452-8235					•		•						•						•
IMPSLR interactive SLR	PEG	250	1980	Princeton Energy Group					•	•								•	•	•			
NEATWORK thermal network	PEG	250	1980	Princeton Energy Group					•	•								•	•	•			•
PEGSOL two-zone	PEG	400	1980	Princeton Energy Group					•	•	•							•	•	•			•
Solarcon Programs for Comprehensive Active System Design (5 programs & 5 sets weather data) (5 insolation models)	R W Graeff	383 data	1977	Solarcon Inc 807 Church Street Ann Arbor MI 48104 (313) 769-6588	•	•	•	•									•	•	•	•		•	
Solarcon Programs for Passive System Design (5 programs & 5 sets weather data)	R W Graeff	495	1979	Solarcon Inc					•	•								•	•	•			
Solar Heating Systems Design Manual	ITT Corporation Fluid Handling Division	2 50	1977	Bulletin TESE-576 Rev 1 ITT Training & Education Dept Fluid Handling Division Morton Grove IL 60053	•	•	•	•							•	•				•			
A General Design Method for Closed-Loop Solar Energy Systems	S A Klein W A Beckman		1977	Proceedings of the 1977 Annual Meeting Vol 1 American Section International Solar Energy Society 1977 pp 81-85			•								•		•			•			
Solar Heating Design by the F-CHART Method	S A Klein W A Beckman J A Duffie	10	1977	John Wiley and Sons New York N Y 1977 (Publisher)	•	•	•	•							•	•				•		•	
TEANEY thermal network model	J T Kohler P W Sullivan	95	1978	Total Environmental Action Inc Church Hill Harrisville NH 03450 (603) 827-3374					•	•	•	•	•				•						•
The GFL Method for Sizing Solar Energy Space and Water Heating Systems	G F Lameiro P Bendt		1978	Rept No SERI-36 Solar Energy Research Institute 1617 Cole Boulevard Golden CO 80401	•	•	•	•							•		•			•			
A Rational Procedure for Predicting the Long-Term Average Performance of Flat-Plate Solar Energy Collectors	B Y H Liu R C Jordan		1963	Solar Energy Vol 7 No 2 1963 pp 53-70	•	•	•	•							•		•			•			
Pacific Regional Solar Heating Handbook	Los Alamos Scientific Lab		1978	Rept No TID-27630 (NTIS)	•	•	•	•							•		•			•			

McClintock Corp	H McClintock	595 Theory volume 175 econ and volume 75	1977	McClintock Corp P O Box 430980 Miami FL 33143 (305) 666 1388	•	•	•	•									•	•	•	•	•					
Minimum Cost Sizing of Solar Heating Systems	J C Ward		1976	Sharing the Sun Vol 4 1976 pp 338 348	•	•	•	•							•		•			•	•	•				
Designing and Building a Solar House Your Place in the Sun II	D Watson	9	1977	Garden Way Publishing Charlotte VT 05445	•	•	•	•							•	•				•		•				
Optimal Sizing of Solar Collectors by the Method of Relative Areas	C D Barley C B Winn	95	1978	Solar Environmental Engr Co Inc	•	•	•	•							•		•				•	•				
SEEC I Heat Load Monthly Solar Fraction Economics (F CHART)	C B Winn	125	1976	Solar Environmental Engineering Co Inc 2524 East Vine Drive Fort Collins CO 80524 (303) 221 5166	•	•	•	•									•	•	•			•				
SEEC II Collector Optimization Annual Solar Fraction Economics	C B Winn D Barley G Johnson J Leftar	95	1978	Solar Environmental Engineering Co Inc	•	•	•	•									•		•	•	•	•				
SEEC III SEEC II Plus Insulation Optimization	C B Winn D Barley G Johnson J Leftar	125 (Calculator version)	1978	Solar Environmental Engineering Co Inc	•	•	•	•									•		•	•	•	•				
SEEC IV Collector Heat Exchanger Sizing and Analysis	C Byron Winn J Leftar	95	1978	Solar Environmental Engineering Co Inc	•	•	•										•									•
SEEC V Duct design and Air Flow Analysis	J Leftar	95	1978	Solar Environmental Engineering Co Inc	•			•									•									•
SEEC VI Passive Solar Heating	K Sharp	125	1978	Solar Environmental Engineering Co Inc							•	•					•	•	•	•	•	•				
SEEC VII Sun Angles and Shading	K Sharp	75	1979	Solar Environmental Engineering Co Inc													•									•
SEEC VIII Swimming Pools	P Jacobs K Sharp	125	1980	Solar Environmental Engineering Co Inc				•									•		•	•	•	•				
Sunshine Power Programs for Modeling Solar Energy Components and Systems Solar Energy Library (9 programs)	G Shearer		1977	Sunshine Power Co 1038 Lamar Drive San Jose CA 95130 (408) 446 7648	•	•	•	•									•		•	•						
Passive Design Patterns (Rule of Thumb in the Passive Solar Energy Book	Edward Mazria	11	1979	Rodale Press Emmaus PA 18049							•	•	•	•	•	•				•	•					
PASCALC Los Alamos SLR	J T Balcomb	PASCALC (Phoenix 75, Lexington 20)	1979	Total Environmental Action Inc Church Hill Harrisville NH 03450							•	•	•				•			•	•	•				
SOLARGRAF/DHW nomographs	W Wright	10	1980	Northeast Solar Energy Center 470 Atlantic Ave Boston MA 02110			•	•							•	•				•						
SOLARGRAF/SLR nomographs	W Wright	10	1980	Northeast Solar Energy Center							•	•			•	•				•						
SUN PULSE II	G Tully	100	1980	McGraw Hill Book Company P O Box 400 Hightstown NJ 08520	•	•	•	•			•	•					•			•						•
G CHART	SEDCLA	25 - tax	1979	Solar Energy Design Corp of America	•	•	•	•							•		•			•		•				
P CHART SLR nomograph	SEDCLA	20 - tax	1980	Solar Energy Design Corp of America							•	•			•	•				•	•	•				
Solar Energy Programs	S A Klein W A Beckman	40	1980	f CHART P O Box 5562 Madison WI 53705	•	•	•	•			•						•			•		•				•
PASODE1 SLR	L P M	300	1980	Lumb Parker Methods Inc Mr Steve Anders 7438 Forsyth South 302 St Louis MO (314) 725 5580							•	•	•							•	•	•	•			
OVERHANG shading	L P M	350	1980	Lumb Parker Methods Inc																•						•
EXFIND hour sim Trombe	L P M	300	1980	Lumb Parker Methods Inc								•	•							•						•
INSULATE econ optimized	L P M	300	1980	Lumb Parker Methods Inc																•						•
LPM12 two zone passive	L P M	1500	1980	Lumb Parker Methods Inc							•	•	•							•	•					

Δ McFarland R D and Jones R W "Performance Estimates for Attached Sunspace Passive Solar Heated Buildings" Proc 1980 AS/ISES Vol 3 2 pp 784 788 Phoenix AZ June 1980

SHAC Computer Methods Summary

The following summary table and text describe the most frequently used and currently available solar analysis computer methods. The information was obtained largely from a program author survey conducted by Arthur D. Little, Inc. for the Electric Power Research Institute and primarily reflects the opinions of each program author.

Most summary table categories are self-explanatory; however, the intended user category needs emphasis. Programs suitable for use by builders were limited to the interactive type program that interrogates the user by a question and answer methodology. Architects/engineers use mainly design-oriented computer programs and generally restrict their analysis to standard input/output options of the program. The research engineer generally has hands-on access to the program and is very familiar with both the operation and assumptions of the program and the details of the system being analyzed.

Program Name	Latest Version	Availability				Application								Intended Users			Computation Interval		Computer Versions Available	Economic Analysis	Sponsor
		Purchase ($)	Time Share	Special Arrangements	Comments	User Manual	Service Hot Water	Space Heating	Space Cooling	Process Heat	Active System	Passive System		Research Engineers	Architect/Engineers	Builders	Hour	Month			
BLAST*	1980	Nom.	•		Training available	•	•	•	•		•	•		•	•		•		CDC	•	USAF, USA, GSA
DEROB	1979	200				•		•	•			•		•	•		•		CDC		NSF, ERDA, DOE
DOE-2*	1980	400	•			•	•	•	•		•	•		•	•		•		CDC	•	LASL, DOE
EMPSS	1978	500		•	Consulting with ADL	•	•	•	•		•	△		•	•		•		IBM	•	EPRI
F-CHART	1978	100	•		Training available	•	•	•			•				•	•		•	CDC, IBM, UNIVAC †	•	DOE
FREHEAT	1979	150			Limited documentation			•				•		•			•		CDC	•	DOE
HISPER	1978	Avail. on request			Limited documentation	△	•	•	•		•			•			•		UNIVAC 1100, PDP		NASA, MSFC
HUD-RSVP/2	1979	175	•		Based on F-CHART	•	•	•			•				•	•		•	CDC, UNIVAC	•	HUD
PACE	1980	150	•		Based on F-CHART, SLR	•	•	•			•	•			•	•		•	CDC, UNIVAC	•	DOE, SERI
SHASP	1978	Avail. on request				•	•	•	•		•			•			•		UNIVAC	•	DOE
SOLAR-5	1979		•		Not Distributed			•	•			•			•	•	•	•	CDC		UCLA, DOE
SOLCOST	1979	300	•			•	•	•			•	•		•	•	•		•	CDC, IBM, UNIVAC	•	DOE
SOLFIN 2	1980	Nom.		•	Documentation Cost $8.	•	•	•	•	•	•	•		•	•	•	Annual		IBM, CDC	•	California Energy Commission
SOLOPT	1978	20				•	•	•			•			•				•	AMDAHL	•	Texas A&M Univ.
SOLTES	1979	175			No Cost for DOE	•	•	•	•	•	•			•			•		CDC		DOE, Sandia
SUNCAT	1979	Nom.			Limited documentation	•		•				•		•	•		•		Data General Eclipse	•	NCAT
SUNSYM*	1979		•	•	Offered as service only	•	•	•	•		•				•		•		IBM	•	Sunworks Comp. Systems
SYRSOL	1978	Nom.			Avail. but not actively marketed		•	•	•		•			•	•	•	•		IBM	•	ERDA, NSF, DOE
TRACE SOLAR*	1980		•	•	Offered as service only	•	•	•	•	•	•			•	•		•	•	IBM	•	The Trane Co.
TRNSYS	1979	200	•		Training required	•	•	•	•	•	•	•		•			•		CDC, IBM, UNIVAC †	△	DOE
TWO ZONE	1977	No Charge		•		•		•	•		•	•		•			•		CDC	•	LBL
UWENSOL	1980	200				•		•				•		•			•		CDC		State of Wash.
WATSUN II, III	1980	Contact Author				•	•	•			•			•			•		IBM	•	Nat'l Research Center of Can

*Programs are primarily developed for large-scale, multi-zone applications

△ Being added

† ANSI 1966 Std. Fortran

Microcomputer Methods for Solar Design and Analysis — Summary

Program Name	Proprietor/Author	Description on Page No.	Equipment Requirements				Energy Conservation	Active Solar
			Machines	Required Capacity of Storage (kilobytes)	Peripherals	Cost $		
INSULATE	Londe, Parker, Michels	4	N∝CT	12	C (P)[2]	300	●	
BILL	Londe, Parker, Michels	5	NC/∝	14	CD (P)	350/400	●	
SUNOP	Solarsoft	7	A	30	CD (P)	250	●	
CL4M	MC↑2 Programs	13	T	48	CD (P)	995	●	
RL5M	MC↑2 Programs	14	T	16	C (P) T/D	95/115	●	
HC3M	MC↑2 Programs	14	T	16	C (P) T/D	75/95	●	
TSWING	Solarsoft	7	A	24	CD (P)	395		●
SUNCODE	Ecotope Group	9	Mini	30-45	CDP	1000		●
STENET	Hewlett Packard Users Group	8	H	14	Matrix ROM	10		●
NEATWORK	Princeton Energy Group	10	APT	8-12	C	250		●
SUNEST	Earth Integral	12	A	48	C (P)	250		●
SUNSIM-1	Solartek	14	T	16	CT	49		●
SE1M	MC↑2 Programs	13	T	16/32	C (P) T/D	175/265		●
SOLARF	Inatome & Associates	16	N	48	CDP	150		●
SOLARG	Inatome & Associates	16	N	48	CP	150		●
SERI F-Chart	Solar Environmental Engineering Co.	17	T	16	CT(P)	200		●
SUNGRAPH	Solartek	15	T	16	CT	49		6
LC2M	MC↑2 Programs	14	T	16	C (P) T/D	95/115		6
ELSOL	Inatome & Associates	15	N	48	CP	150		6
PASODE 1	Londe, Parker, Michels	5	N∝CT[1]	20/16	C (P) D/T	300		
SUNMAT	Solarsoft	6	A	45	CD (P)	250		
HELIOS	Leonard A. Rydell, P.D.	8	N	48	CDP	480		
MICROFIX	Princeton Energy Group	10	APTH	7-17	C (P)	150		
IMPSLR	Princeton Energy Group	10	APT	24-28	CD	250		
PEGSOL	Princeton Energy Group	11	P	29	C (P) D/T	400		
LASL2	Earth Integral	11	T	32	C (P)	75		
LASL6	Earth Integral	11	AT	32	C (P)	50		
SERI-SLR	Solar Environmental Engineering Co.	16	T	16	CT (P)	200		
OVERHANG	Londe, Parker, Michels	4	N∝CT	16	C (P)	350		
EXFIND	Londe, Parker, Michels	5	∝C	28	CDP	400		
LPMTZ	Londe, Parker, Michels	6	N∝C	43	CDP	695		

Machine Codes —
- N Northstar
- ∝ Alpha Micro
- C CPM C-Basic
- T TRS-80 (Radio Shack)
- A Apple
- H HP-85 (Hewlett Packard)
- P Commodore PET (CBM)

Peripheral Codes —
- C CRT Screen
- P Printer
- D Disk Drive
- T Tape Drive

Application									Method								Results										
Passive									Simulation		Correlation			Frequency of Iteration								Output Time Step					
Water Wall	Trombe Wall	Direct Gain	Sun-Space	Space Heating	Space Cooling	Hot Water	Economics	General	Explicit	F-Chart	SLR	Calculation	Hourly	Daily	Monthly	Annual	Radiation	Auxiliary Load	Temperatures (Zone or Nodal)	Component Optimization	Payback/Savings	Cost of Energy	Hourly	Daily	Monthly	Annual	Program Name
				●	●		●					●				●				●	●	●				●	INSULATE
				●	●							●			●			3				3			●		BILL
				●	●							●				●				●	●	●				●	SUNOP
●	●	●	●	●			●					●				●		●					●				CL4M
				●	●							●	●					●					●				RL5M
				●	●							●	●					●				●				●	HC3M
				●			●					●				●	●	●	●	●			●	●			TSWING
●		●	●	●	●			●					●				●	●	●				●		●	●	SUNCODE
●	●	●	●	●	●				●				●				●	●	●				●	●			STENET
●	●				●			●					●					●	●				●	●			NEATWORK
●	●	●	●	●	●			●					●					●	●				●		●	●	SUNEST
●	●	●		●	●	●								●		●		●	●					●		●	SUNSIM-1
				●	●	●				●				●				●				●	●			●	SE1M
				●		●	●				●					●		●				●				●	SOLARF
				●		●	●				●					●		●				●				●	SOLARG
				●		●	●				●					●		●				●				●	SERI F-Chart
				●		●	●				●					●		●			●	●	●			●	SUNGRAPH
6				●		●	●						●	●	●			4						●	●	●	
6								●					●									●	●				●	LC2M
6					●	●	●						●	●		●		●										ELSOL
●	●	●		●				●				●	●			●						●	●			●	●	PASODE 1
●	●	●		●								●		●		●		●			●					●	●	SUNMAT
●	●	●	●	●								●				●		●					●			●	●	HELIOS
●	●	●		●								●				●		●	●					●	●			MICROFIX
		●	●	●	●	●				●					●			●					●			●	●	IMPSLR
●	●	●			●							●				●		●	●					●	●			PEGSOL
●		●	●	●	●	●				●								●	●							●	●	LASL2
●	●	●			●							● [5]				●		●					●			●	●	LASL6
●	●				●							● [5]				●		●					●			●	●	SERI-SLR
●	●	●	●	●	●							●				●	●	●								●		OVERHANG
	6					●	●							●	●	●		●										EXFIND
		●	●	●						●					●				●	●	●			●	●	●	●	LPMTZ
		●	●	●	●	●				●					●												

Notes:
1. An oblique (/) indicates a distinction carried across the line, such as here, the TRS-80 version requires only 16K bytes of memory and a tape drive rather than the disk.
2. Parentheses indicate that the program incorporates statements for obtaining printed output, but that a printer is not necessary for the use of the program
3. Finds correlation between weather and monthly fuel bills
4. Finds solar position
5. Uses the original SLR method
6. Application to all solar systems

APPENDIX C

Public Works Canada/Energy, Mines and Resources
Survey to Identify Current and Future Requirements
for Software Support and Development for Energy
Analysis and Energy Efficient Design.

Public Works Canada
Assistant Deputy Minister

Travaux publics Canada
Sous-ministre adjoint

18 January 1982

Our File
6232-5

le 18 janvier 1982

Notre référence
6232-5

Mr. Eric Burnette
Waterloo Research Institute
University of Waterloo
Waterloo, Ontario
N2L 3G1

Dear Sir/Madam:

Subject: Survey to Identify Current and Future Requirements for Software Support and Development for Energy Analysis and Energy Efficient Design

As part of a National program to promote energy conservation in buildings, Public Works Canada, with funding from Energy, Mines and Resources have identified a program of work, for the review, support and development of Energy Analysis tools.

Mr. Eric Burnette
Waterloo Research Institute
University of Waterloo
Waterloo, Ontario
N2L 3G1

Monsieur/Madame,

Objet: Détermination par sondage des besoins actuels et futurs de soutien et de développement en matière de logiciel pour l'analyse énergétique et la conception d'immeubles à rendement énergétique élevé

Dans le cadre d'un programme national visant à promouvoir les économies d'énergie dans les immeubles, Travaux publics Canada, grâce à des fonds fournis par Énergie, Mines et Ressources, a défini un programme de travail, en prévoyant l'examen et la mise au point d'instruments d'analyse énergétique ainsi que la prestation du soutien nécessaire à leur utilisation.

...2

Sir Charles Tupper Building
Riverside Drive
Ottawa
K1A 0M2

Édifice Sir Charles Tupper
Promenade Riverside
Ottawa
K1A 0M2

Canada

The intent of this program is to:

(i) review existing analysis tools and evaluate their usefulness to Canadian construction activities;

(ii) perform required development on the selected tools and/or their documentation to facilitate their effective use;

(iii) provide for support of the tools on a long-term basis in all aspects of marketing, training, program refinement, technical assistance to users and documentation.

The program is currently in the "Review" stage. During this review, Public Works wish to get as wide an input as possible as to just what the industry would like to see in the way of support and development of energy analysis programs.

In carrying out this review we wish to broaden the area of concern beyond that which is normally associated with energy analysis programs to include all aspects of the building design process that impact upon the energy use of the building and as such should include:

(i) techniques applicable to both new building design and existing building retrofit evaluation;

(ii) techniques encompassing all design stages from concept through to final design;

L'objet du programme consiste à:

(i) procéder à l'examen des instruments actuels d'analyse et évaluer leur utilité dans le contexte des activités de construction au Canada;

(ii) procéder à la mise au point voulue des instruments choisis et (ou) à l'établissement d'une documentation connexe visant à faciliter leur utilisation et à accroître leur efficacité;

(iii) assurer un programme de soutien à long terme pour l'utilisation des instruments dans les domaines de la commercialisation, de la formation, du perfectionnement des programmes et de la documentation ainsi que de l'aide technique à l'intention des utilisateurs.

Le programme est actuellement au stage d'"examen". Au cours de cet examen, Travaux publics souhaite obtenir le plus de paramètres possibles sur ce que l'industrie envisage comme éléments de soutien et de développement en matière de programmes d'analyse énergétique.

Lors de la réalisation de cet examen, nous désirons élargir le secteur visé et aller au-delà des questions normalement reliées aux programmes d'analyse énergétique afin d'englober tous les aspects conceptuels de l'immeuble qui ont des incidences sur sa consommation énergétique et, à ce titre, il faudrait inclure:

(i) les techniques applicables à l'évaluation des projets de conception des nouveaux immeubles ainsi que de rénovation des immeubles existants;

(ii) les techniques englobant toutes les étapes de la conception, à partir de l'étude conceptuelle jusqu'à la conception définitive;

. . . 3

(iii) techniques permitting the evaluation of lighting and daylighting schemes, building envelope, mechanical and electrical design problems and the evaluation of passive and active solar systems.

The attached questionnaire has been designed to obtain certain basic information about your:

(i) present computer facilities;

(ii) current use of computers;

(iii) present and planned use of energy analysis techniques or conversely the reasons why you do not currently use such techniques.

We would be obliged if you could take some time to complete the questionnaire and return it in the envelope provided within 10 days of receiving this letter.

Please indicate on the questionnaire if you would be prepared to take part in one of several small discussion meetings which we plan to hold in several locations throughout Canada.

(iii) les techniques permettant l'évaluation des méthodes d'utilisation de l'éclairage artificiel et naturel, de l'enveloppe des immeubles, des problèmes de conception des installations mécaniques et électriques et des installations solaires à systèmes actifs et passifs.

Le questionnaire ci-joint a été conçu afin de nous permettre d'obtenir certains renseignements de base au sujet de:

(i) vos installations informatiques actuelles;

(ii) l'utilisation que vous faites présentement des ordinateurs;

(iii) l'utilisation actuelle et prévue des techniques d'analyse énergétique ou encore des motifs pour lesquels vous n'utilisez pas actuellement ces techniques.

Je vous saurais gré de bien vouloir consacrer un peu de votre temps à répondre au questionnaire et à le renvoyer dans l'enveloppe ci-jointe dans les dix jours suivant la réception de la présente lettre.

Veuillez indiquer sur le questionnaire si vous aimeriez participer à l'une des petites réunions de discussion que le Ministère prévoit tenir en plusieurs endroits au Canada.

. . . 4

A second attachment, entitled "discussion document", is circulated with the intent of raising some issues with respect to energy modelling. It is not essential that you read this document in order to complete the questionnaire. It is, however, the issues raised in this document, and any other you may add, that we plan to discuss in the meetings. It would, therefore, be useful to review this document if you are considering participating in one of the meetings. If you require any additional time or have any questions, please call Dr. E.L. Morofsky at (613) 998-9135.

Note that the information obtained from the questionnaire and discussion meetings will be used to formulate a program for development and support of energy analysis software for use by all Canadian designers, not just those working on Federally funded projects. This is your chance to influence that choice.

Yours truly,

Un deuxième document intitulé "document de travail" est diffusé en vue de susciter certaines questions relativement à l'établissement de modèles énergétiques. Il n'est pas essentiel que vous lisiez ce document pour remplir le questionnaire. Mais il serait sûrement utile de le lire si vous avez l'intention de participer à l'une de ces réunions, comme nous prévoyons discuter des questions figurant dans ce document ainsi que de toute autre que vous pourriez soulever. Si vous avez besoin d'un délai supplémentaire ou si vous désirez obtenir un renseignement quelconque, veuillez communiquer avec M. E.L. Morofsky au numéro de téléphone (613) 998-9135.

Permettez-moi de souligner que les renseignements recueillis à l'aide du questionnaire ou lors des réunions de discussion serviront à formuler un programme de soutien et de développement en matière d'un logiciel pour l'analyse énergétique qui serait à l'usage de tous les concepteurs canadiens, et non pas seulement à l'intention de ceux qui travaillent à la réalisation de projets financés par le gouvernement fédéral. Nous vous offrons donc l'occasion d'influencer notre choix.

Veuillez agréer, Monsieur/Madame, l'expression de mes sentiments distingués.

Le Sous-ministre adjoint,
(Design et construction)

Guy Desbarats,
Assistant Deputy Minister,
Design and Construction.

Attachs.

p.j.

PLEASE READ THE COMPLETE QUESTIONNAIRE BEFORE ANSWERING THE QUESTIONS.

IT IS NOT NECESSARY THAT YOU READ THE ATTACHED DISCUSSION DOCUMENT IN ORDER TO COMPLETE THE QUESTIONNAIRE.

IT IS, HOWEVER, SUGGESTED THAT YOU READ THE DOCUMENT IF YOU ARE INTERESTED IN PARTICIPATING IN ONE OF THE PLANNED DISCUSSION MEETINGS.

1 GENERAL INFORMATION

Company name _____

Address _____

_____

_____

Telephone No. _____

Contact Person _____

Total Number of Employees _____

Is this a parent or branch office? _____

2 Which of the following classifications best describes your organization and principal occupation? (CHECK ONLY ONE FROM EACH COLUMN)

Architects	☐	Architect	☐
Consulting Engineers	☐	Engineer	☐
Architects-Engineers	☐	Teacher	☐
University	☐	Researcher	☐
Building Developer	☐	Other (please specify)	
Construction Company	☐	_____	
Government Department	☐		
Other (please specify)			

_____

3 Does your firm use computers in any way in its operations? (EXCLUDE WORK SUB-CONTRACTED TO OTHERS)

Yes ☐ No ☐

4 Does your firm currently use, or plan to use, computers in any aspect of the design process? (EXCLUDE ACCOUNTING AND FINANCIAL AND PERSONNEL MANAGEMENT USES.) Yes ☐ No ☐

(If NO, please skip to question 9)

5 If YES, how are the computer services provided? Give approximate purchase cost if you own the computer, otherwise give estimated annual cost.

Firm owns a computer Indicate type _____	$ ☐
Firm leases a computer	$ ☐
Firm uses a commercial time-sharing service (real-time, on-line access, etc.)	$ ☐
Firm uses a commercial service bureau (usually only batch processing)	$ ☐
Computer services sub-contracted	$ ☐
Other (please specify)	
(i) _____	$ ☐
(ii) _____	$ ☐

6 What are the primary reasons why your firm employs computer techniques in the design process? (RANK IN ORDER OF IMPORTANCE, i.e. enter "1" for most important, "2" for second most important, etc.)

To reduce design costs.	☐
To carry out tasks which would not be practical using manual techniques.	☐
To improve the quality of designs.	☐
To reduce the number of design errors.	☐
To speed up the design process.	☐
To standardize methods.	☐
In order to comply with building codes and/or specific project requirements.	☐
Other (please specify)	
(i) _____	☐
(ii) _____	☐

7 In which aspects of the design process does:-

(i) your firm currently use computers;

(ii) your firm plan to use computers; and

(iii) do others use computers on your behalf?

	Firm Uses	Firm does not now use but plan use (Next 12 months)	Use by Others on Your Behalf
Energy analysis	☐	☐	☐
Mechanical engineering	☐	☐	☐
Lighting analysis	☐	☐	☐
Electrical engineering	☐	☐	☐
Civil engineering	☐	☐	☐
Structural engineering	☐	☐	☐
Cost estimating	☐	☐	☐
Life-cycle costing	☐	☐	☐
Perspective drawing	☐	☐	☐
Drafting	☐	☐	☐
Specifications	☐	☐	☐
Other (please specify)			
(i) _____	☐	☐	☐
(ii) _____	☐	☐	☐
(iii) _____	☐	☐	☐
(iv) _____	☐	☐	☐

QUESTIONS (8) TO (14) RELATE SPECIFICALLY TO THE USE OF ENERGY ANALYSIS PROGRAMS.

8 (i) For what percentage of all new design projects are energy analysis programs used? ☐

(ii) For what percentage of all retrofit design projects are energy analysis programs used? ☐

(iii) What are the relative percentages of new and retrofit design work?

new design ☐ retrofit design ☐

9 If you are not currently using energy analysis programs check primary reasons why not. (RANK IN ORDER OF IMPORTANCE, "1" = most important)

Inadequate support	☐
Inadequate programs	☐
Costs outweigh benefits to user	☐
Difficult to use	☐
Lack of trained staff	☐
Benefits not acknowledged by client	☐
Other (please specify)	
(i) _____	☐
(ii) _____	☐
(iii) _____	☐
(iv) _____	☐
(v) _____	☐

10 Indicate those programs that you have used; are currently using; plan to use, or continue to use. (CHECK ALL THAT APPLY)

	Have Used But not in the last 12 months	Now Using (i.e. used in last 12 months)	Plan to Use or continue to use within next 12 months
DOE	☐	☐	☐
BLAST	☐	☐	☐
ESA (MERIWETHER)	☐	☐	☐
APEC ESP	☐	☐	☐
TRACE	☐	☐	☐
ECUBE	☐	☐	☐
CARRIER'S E20-II	☐	☐	☐
OTHER (State if developed "in House")			
(i) _____	☐	☐	☐
(ii) _____	☐	☐	☐
(iii) _____	☐	☐	☐
(iv) _____	☐	☐	☐

Do you have any comments on the program(s) you are using? _____

11 If you are carrying out energy analysis, or have the past, indicate those areas you try to evaluate. nk in order of 'most used' = 1, 'often used' = 2, ccasionally used' = 3

- enclosure U value ☐
- glazing area ☐
- building form and orientation ☐
- HVAC system type ☐
- HVAC system operation ☐
- control strategies ☐
- heat recovery "air-side" ☐
- central plant configuration ☐
- central plant heat recovery ☐
- solar heating ☐
- solar dhw ☐
- other (please specify)
  - (i) _____
  - (ii) _____
  - (iii) _____
  - (iv) _____
  - (v) _____

y Comments?

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

12 Indicate, in order of preference, those areas that you feel the Federal Government should support energy analysis programs. (Enter "1" for most preferred, "2" for second, etc.)

- (i) No support felt necessary. ☐
- (ii) Subsidise development and support at commercial computer bureaus. ☐
- (iii) Develop and support programs at a Federal Government agency. ☐
- (iv) Support courses in Universities and Technical Colleges. ☐
- (v) Subsidize computation and/or program royalty costs. ☐
- (vi) Develop and support programs through a separate non-profit organization initially funded by the Federal Government but ultimately to be supported by the industry itself. ☐
- (vii) Indicate the annual amount, if any, that you would consider contributing to such an organization. If you are not willing to contribute enter "0" Other (please specify) ☐
  - (i) _____
  - (ii) _____
  - (iii) _____
  - (iv) _____
  - (v) _____

13 Include any written comments below. (These can be general comments, comments on any specific item in this questionnaire or, if you have read it, comments on points raised in the discussion document.)

14 Indicate whether or not you would be prepared to take part in one of a series of meetings to be held across Canada to discuss this program.

YES ☐ NO ☐

APPENDIX D

Public Works Canada/Energy, Mines and Resources. Discussion Document re "Current Limitations and Future Possibilities for Energy Analysis Techniques".

DISCUSSION DOCUMENT

THIS DOCUMENT IS PROVIDED TO PROVOKE SOME THOUGHTS ON CURRENT LIMITATIONS AND FUTURE POSSIBILITIES FOR ENERGY ANALYSIS TECHNIQUES. IT SHOULD NOT BE CONSTRUED AS A SPECIFICATION FOR THE TYPE OF SOFTWARE WE ARE PLANNING TO DEVELOP AND/OR SUPPORT. MANY OF THE POINTS ARE PURPOSELY CONTENTIOUS.

DOCUMENT DE TRAVAIL

LE PRÉSENT DOCUMENT VISE À SUSCITER CERTAINES OPINIONS SUR LES RESTRICTIONS ACTUELS ET LES POSSIBILITÉS FUTURES DES TECHNIQUES D'ANALYSE ÉNERGÉTIQUE. IL NE FAUDRAIT PAS QU'IL SOIT CONSIDÉRÉ À TORT COMME UN MODÈLE POUR LE GENRE DE LOGICIEL QUE NOUS PRÉVOYONS DÉVELOPPER ET (OU) APPUYER. DE NOMBREUX POINTS SONT LITIGIEUX À DESSEIN.

PROBLEM	COMMENT
(1) Batch mode operation of running energy analysis programs is not consistent with the "design process" which is "interactive". This is particularly true at concept or preliminary design stage where batch operation is much too slow.	Modify programs to run interactively.
(2) The fact that good design, aided by computer techniques, can reduce the capital cost of a building most often leads to reduced fees for the building designers. This is viewed to be a major disincentive to the use of computer design techniques.	Change present fee structures.
(3) 'Big Energy Programs' such as Meriwether are expensive to use at concept design, both in data input and machine time.	Use simple program or use "big program" with defaults for data not generally available or particularly relevant at concept stage and minimize the number of hourly simulations.
Often the level of data input is not consistent with the design problem or the discipline.	Use micro and mini computer for local data input, processing, checking, etc., to minimize bureau costs.
(4) Window Evaluation. It is not possible with present techniques to evaluate windows in terms of their thermal and visual performance.	Develop or introduce daylighting/artificial lighting algorithms into the energy programs, or provide complementary lighting programs that could swap data with the energy program.
(5) Using a computer program not knowing what assumptions and algorithms and simplifications have been made by the program author (the "black box" program) is viewed by many to be unsatisfactory.	Make program code, assumptions, algorithms used, etc., available to the program user.
(6) Non portability of programs can limit purchase and use of programs due to difficulty of compilation. Also, user may have to learn operating systems of more than one computer bureau in order to have access to all the software he needs.	Make software available and operational on all major systems or provide a single comprehensive system.

PROBLEM	COMMENT
(7) Design Options are limited and programs tend to be out of date and lag the newest ideas. Typical comments include: "Innovative design is limited by fixed system and option type program." "Canned Programs severely limit ingenuity." "Danger is that designers may be forced to follow a course whereby their designs are constrainted by the software."	Continue expanding programs on ad-hoc basis or develop component based software or allow or promote changes by program users. Component based systems appear the most attractive option but the practicalities of developing and using such programs require careful evaluation.
(8) "Program Authors and Computer Bureaus are generally reluctant to talk about the limitations of their programs." Further, there is no commonly accepted criteria for evaluating load and energy analysis programs. This is particularly troublesome for the small user who wants to pick the best program(s) for his particular needs.	Programs could be reviewed, critiqued, supported, and made available through independent body - i.e., 'non-profit organization' supported by Government and/or industry.
(9) Whilst the concept of designing an optimum building, i.e., minimum life cycle cost, is probably not feasible due to the immense number of variables, sub-optimization may be feasible.	Consider automatic or semi-automatic optimization routines for sub-systems with the main program structure. Example 1 - Optimum solar collector sizing for minimum solar energy cost. Example 2 - Optimizing solar shading.
(10) Simulation of controls and Central Control and Monitoring Systems is limited by current coding and calculation carried out at one-hour time intervals.	Modify coding and change time interval. This would, however, have a significant effect on cost of computation unless some form of time sampling used.
(11) Interzone heat transfer - particularly at "imaginary boundaries" such as "interior" and "exterior" zones in an open plan office and between source and sink in passive solar designs is considered a source of weakness in current programs. This is also true, if not more so, of air ~~to air~~ flow between zones.	Select program(s) currently with best modelling or program whose structure would permit zone to zone heat and air transfer to be modelled. Some research, however, is probably required to provide satisfactory models. Such changes will most probably increase cost of computation.

PROBLEM	COMMENT
(12) Evaluation of life cycle cost at concept design is generally not practical with current programs.	Provide life cycle cost model(s) that would allow, for example, comparative evaluation of life cycle cost of window based on energy implications of glazing and relative costs of wall and window/shade combination.
(14) Infiltration is treated poorly in most current energy programs.	Replace infiltration algorithms with state of the art versions. One of the major problems, however, is with the input of reasonable data. For example, what is the envelope leakage and when does it occur?
(13) Underground heat transfer is generally poorly modelled. Problem generally more relevant to domestic and small compact buildings or large one or two-storey buildings and to 'earth protected' structures.	Upgrade algorithms in existing program(s) if considered inadequate. As with above, however, input data is a problem. For example, there is a real problem defining surrounding soil conditions.
(15) Domestic hot water simulation, particularly solar system simulation, is limited by the ability to analyse realistic water profiles.	Develop models for producing building water use profiles. Models may need to be stochastic to accommodate day-to-day variations in water draw.
(16) Users of programs often have difficulty with "Job Control Language" (JCL) and bureau operating system. This is aggravated if the user has to access programs at different bureaus.	Provide simple, preferably single, operating system that can be used for all energy and design programs.
(17) Equipment performance data, when available, has to be input manually increasing potential for error. This is particularly relevant for lighting equipment where photometric data is quite lenghty.	Provide a data base of equipment performance characteristics.
(18) Control systems that rely on the interaction between systems and central plant cannot be modelled with most programs since system and plant programs normally are unlinked, i.e. they run independently. This limits, for example, the evaluation of chilled water reset with space load variations and "optimized start" of heating and cooling systems.	Select program(s) with system-plant linkage or select program capable of being modified.

PROBLEM	COMMENT
(19) It has been stated that it will be a long time before the architect will give up his "soft lead" approach to concept design and adopt computer aided design.	Consider possibility of graphical input (by light pen?) directly into an energy analysis model.
(20) Simplified Methods Whilst there are numerous requests for a simplified model there have been several reservations expressed about their use. Some are given below.	
(i) Oversimple calculation can give a wrong or poor answer. The use of simple techniques at concept design, if used unwittingly, could set the building design off on the wrong track.	
(ii) Whilst people want a simple program what they really want is a large program with unlimited options that is easy to use!	Use sophisticated model with defaults. Flag user when he carries out parametric runs for which defaulted values have a significant effect on results.
(iii) The use of more than a single energy program can fragment the design process, especially if different programs are used by different disciplines.	
(iv) The use of a simple program prevents the user from learning and advancing his modelling abilities as he becomes more familiar with the software.	
(v) Having more than one program increases learning time.	
(vi) Inherent differences in the numbers produced by different programs (and different analysts) may be difficult to rationalize when moving from one program to another.	

PROBLEM	COMMENT
(21) From work carried out by the International Energy Agency Working Group on Buildings and Community Systems it was concluded that the differences in cooling loads calculated by different programs resulted mainly from the modelling of the space heat transfer, notably the way in which building storage effects were handled.	Evaluate modelling method and its general range of applicability when selecting software. Consider using more sophisticated room heat balance method to accommodate possible improvement to current transfer function method using menu of typical room transfer functions.
(22) Energy analysis does not currently "integrate" well with the design process and is not "cost effective" to the architect or consultant.	Develop overall program package that allows multi-use of data. For example, there is similarity in the date required for equipment sizing and energy estimation. The same data could be used to achieve both results. Some examples are given below.
(i) Concept design energy evaluation (and life cycle costing)	Use of the same quality of data as required for the complex finished design analysis is theoretically the ideal but in practice unrealistic. Much simplication is required, since many of the final details are not quantifiable at concept design.
(ii) Mechanical and electrical equipment sizing (detail design stage)	The input data is essentially the same for equipment sizing (including heating and cooling load calculations) and energy analysis. If anything, the equipment sizing may require a finer level of detail than is normally required of the energy analysis, particularly where terminal units and air volumes are sized.
(iii) Control System Design	Control system modelling is implicit in energy analysis. Improved control system evaluation would, however, require a finer level of detail and calculations made at time intervals of less than one hour.

PROBLEM	COMMENT
(iv) Design checking by designer or by client's engineer or building code officer	Obviously the same detail as used in the complex analysis could be used, but this is both lengthy and subject to repetition of same errors. Automatic machine reduction of detailed data to some simple data which could then be checked by running a simpler program, or against details from drawings, might be feasible.
(v) Pipework and ductwork design	Requires load details and pipework layout. Loads could be directly obtained from Load/Energy program. Depending on program, Building geometry as defined in the Energy program could help in pipework and ductwork layout. Advantage could possibly be taken of diversity if system sized from coincident loads from the energy program as opposed to arithmetic sum of peak loads as is common practice.
(vi) Lighting and daylighting	Building geometry, solar and shading routines may have overlap with daylight component. Output from lighting program - particularly from daylight assist installation - could be used as input to the energy program to accommodate lighting heat gain and electricity use.
(vii) Estimating and specifications	Building and system description as used in the energy analysis could be used to assist in the production of "bills of materials" and specifications.
(viii) Drafting and sketching	Define the building geometry which is required for the energy analysis.

PROBLEM	COMMENT
(ix) Elevator and other transportation systems	Minimal data overlap - possibly potential in building geometry and schedule of occupancy. Output from elevator program could be used as input to energy program to accommodate elevator electrical usage.
(x) Electrical distribution	Electrically driven equipment loads are required for distribution system design. Loads should be available from the energy program. Some advantage could be taken of diversity in loads to minimize main cable sizes - such diversity could be ascertained from hourly output from the energy program. Also potential use for planning electrical demand limiting systems and power factor evaluation (lightly loaded motors run at poorer power factor).

POOR

QUALITY

ORIGINAL